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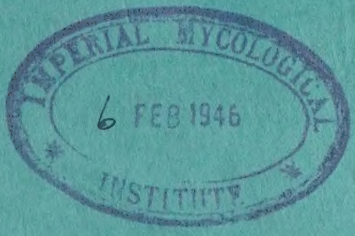
MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

XXX (1944)

PART I: BOTANY AND FORESTRY



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MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

VOLUME XXX (1944)

PART I: BOTANY AND FORESTRY

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PART I: BOTANY AND FORESTRY

PART II: ZOOLOGY

PART III: GEOGRAPHY AND GEOLOGY

PART IV: GENERAL SECTION

ANTHROPOLOGY, ECONOMICS
LANGUAGE AND LITERATURE
MEDICAL SCIENCE, SOCIOLOGY

PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

EDITORS
EUGENE S. McCARTNEY
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VOLUME XXX (1944)
PART I: BOTANY AND FORESTRY

"Pusilla res mundus est nisi in illo
quod quaerat omnis mundus habeat."
— SENECA, *Naturales Quaestiones*

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SILICIFIED PLANT REMAINS FROM THE MESOZOIC AND TERTIARY OF WESTERN NORTH AMERICA

I. FERNS

CHESTER A. ARNOLD

INTRODUCTION

THE silicified plant remains of the Mesozoic and Tertiary of western North America have offered many opportunities for paleobotanical research, which often have been neglected. Although the scarcity of properly trained investigators has been partly responsible for this neglect, a more important element has been the prevailing notion that the material consists only of the secondary wood of gymnosperms and dicotyledons which is so difficult to identify that the effort expended would not be justified by the results obtained. Another deterrent, and one of a practical nature, is that most of these woods are as hard as quartz, and the preparation of thin sections suitable for study requires labor, patience, persistence, and a certain minimum of skill. In addition, properly constructed cutting equipment must be available when any amount of material is to be studied. Cellulose peels, which have been widely used within recent years for coal-ball petrifactions, cannot always be successfully made from silicified plants because the etching process often destroys the tissue structure. It is only in woods, usually those with a very dark color, in which the cell walls have retained much of their original organic content, that the intercellular and intracellular silica can be dissolved away without the structure suffering severe damage. The brighter and more brilliantly colored woods are usually without much cell structure, and they cannot often be successfully studied even in ground preparations.

Regardless of the technical difficulties that may be encountered in studying silicified plant remains, some spectacular results have been achieved, as is shown by the investigations of Lester F. Ward and George R. Wieland on the cycadeoids of the Black Hills and

Freezeout Mountain regions of South Dakota and Wyoming. In this group of extinct plants the vegetative and reproductive structures have been analyzed to a degree of completeness approaching that of Recent species. Then there are other instances, on a much smaller scale, of noteworthy achievements in the study of silicified plants from the western states, but no groups other than the cycadeoids have been subjected to thoroughgoing and systematic investigations. Leaf impressions, on the other hand, have been ardently collected in prodigious quantities for nearly a century. Important results have been obtained, and the literature relating to them amounts to volumes. Although they require no elaborate preparations for study, as do petrifactions, their correct interpretation is often a subtle matter which may tax the ingenuity of even the most experienced investigators.

Plant morphologists showed us long ago that relationships are sometimes revealed through internal structure when external form fails. This is especially true in paleobotany, for the whole plant with all parts attached is seldom found. An outstanding example of this principle was the discovery during the latter part of the last century of petrified stems in the Coal Measures which showed a combination of filicinean and cycadean characteristics, but which occurred among foliage ordinarily regarded as belonging to ferns. The conclusion based upon the anatomical evidence was that here exists a member of an extinct group occupying intermediate status, a supposition later substantiated when seeds were found attached to the foliage. Thus, the greater the evidence that can be brought to bear upon any particular problem, the more conclusive the results will be. Anatomical evidence has been used more extensively for Paleozoic plants than for later ones, but it is a useful adjunct even in the classification of Recent species.

The majority of the silicified plants of western North America are woody dicotyledons, followed in decreasing order by conifers, monocotyledons (principally palms), cycadeoids, and ferns. As has been stated, only the cycadeoids have been comprehensively studied. The present account is concerned with two new genera and five new species of ferns which range from the early or middle Cretaceous into the Eocene. The assembling of the material was made possible only through the coöperation of several collectors, most of whom are residents of the regions from which it came. Those who have

furnished or lent specimens for study are Mr. V. D. Hill, Mr. J. W. Berry, Mrs. Ethel Smith, Mr. H. Timmel, Mr. and Mrs. F. W. Dennler, Mr. George Futa, Mr. Fred Salfisberg, and the late Mr. Louis Wessel.

I. AN *OSMUNDITES* FROM CENTRAL OREGON

To date only two structurally preserved stems of *Osmundites* have been reported from North America. *O. skidegatensis* was described by Penhallow (16) from the Lower Cretaceous of the Queen Charlotte Islands in 1902, and in 1941 Daugherty (10) described *O. walkeri* from the Triassic of Arizona. The discovery of a third specimen in the Tertiary of Oregon is of special interest in that it supplies evidence, in addition to that furnished by foliage compressions, of the westward extension during that period of osmundaceous ferns which at present in North America are restricted to the eastern part of the continent.

The specimen, a transverse slice about 3 cm. in thickness of a silicified stem approximately 6 cm. in diameter, was noticed by the author among a collection of agates owned by Mr. V. D. Hill, of Salem, Oregon. Mr. Hill very kindly submitted a portion of the specimen for study. The stem was originally found by other persons, who refused to divulge the exact source, but inquiry has revealed that it came from within ten miles of Post, Oregon. For this reason it seems improbable that the specimen could have come from any formation other than Tertiary. Post is located on the Crooked River slightly to the southwest of the center of the state, and the formations in that region range from early Tertiary to Miocene. The oldest formation in the vicinity of Post is the Clarno, which is believed to be either Eocene or early Oligocene. The Clarno is overlain uncomformably by the John Day series. The lower portion of the John Day series contains the Bridge Creek plant-bearing shales, which are believed to be of upper Oligocene age. Above the John Day is the Columbia lava, followed by the Mascall formation, which belongs to the Miocene. No Cretaceous or older beds have been definitely recognized nearer than Paulina, which is about thirty miles from Post.

Plants have been found along the Crooked River in the Clarno and Bridge Creek shales, and the largest flora was secured from the

latter at Gray's Ranch, eleven miles east of Post (Chaney, 8). These plant occurrences offer no proof, however, that the *Osmundites* stem came from the Clarno or the Bridge Creek beds, because silicified plant material is common in the Tertiary sediments throughout the whole area. Nevertheless, the presumptive evidence is that it is not older than Eocene or younger than Miocene.

The specimen is highly agatized, and although its tissues are very poorly preserved, its generic identity is evident even upon casual observation. In the center are two vascular cylinders which diverge slightly from one transverse surface of the specimen to the other. This shows that the cut was made just above a fork in the stem (Pl. I, Fig. 1). Both axes are enclosed by a thick mantle of adhering leaf bases which in osmundaceous ferns, both living and fossil, makes up the bulk of the trunks. The leaf bases are oval in cross section, with a C-shaped vascular strand in which the concavity is turned toward the center (Pl. I, Fig. 2). At one side of the specimen the outermost leaf bases are oriented in the opposite direction, which shows that the stem had forked a second time at a lower level (Pl. I, Fig. 1, at left). Since branching is infrequent in the living species of *Osmunda*, it is remarkable to find evidence of two rather close dichotomies in a fossil specimen.

Each vascular cylinder is about 6 mm. in diameter. Tissue preservation is very poor, and about all that can be said concerning the structure is that the xylem appears to consist of sixteen or more separate strands around a central pith. The distribution of the phloem and the endodermis, features essential in comparing material with Recent species, is undeterminable. Around the almost clear silica-filled vascular region is the brownish cortical layer through which several leaf traces pass. In the cortex the xylem of the trace is a small reniform mass of tracheids (one of the few places where cells can be seen) with the indentation innermost. As the trace emerges from the cortex the indentation becomes deeper and the petiole base is surrounded by a layer of dark-brown supporting tissue. Those petioles to the outside of the mantle become increasingly larger until they reach a maximum tangential diameter of about 7 mm. Passing outwardly in a more or less horizontal direction among the petiole bases are numerous adventitious roots (Pl. I, Fig. 2).

The geological history of the Osmundaceae is better known than that of most Recent fern families. Structurally preserved stems

known as *Zalesskya* and *Thamnopteris*, which are undoubtedly members of the Osmundaceae, occur in the Permian. There are no undisputed records of osmundaceous ferns in older Paleozoic rocks, although the family may be foreshadowed by fructifications and stems of the Lower and Upper Carboniferous usually assigned to the Botryopteridaceae. Stems definitely referable to *Osmundites* are known from the Triassic rocks (Kidston and Gwynne-Vaughan, 13; Daugherty, 10), but the genus appears to have reached the height of its development during the Jurassic.

Osmunda (*Osmundites*) is rare in the Tertiary of North America, probably having disappeared entirely from the western part of the continent during the middle or the latter part of that period. It is rarely found in rocks younger than Eocene, and is not common even there. However, it is possible that from time to time the genus has been overlooked because of the ease with which the barren foliage may be mistaken for that of other genera. The frond fragments described by C. C. Hall (in Chaney, 8, p. 100) as *Pteris silvicola*, from the Gray Ranch along the Crooked River, are quite similar to the normal frond parts of the eastern *Osmunda cinnamomea*, and could, it seems, be assigned to this species as readily as to the bracken fern. The bracken, of course, is a member of the coastal redwood association with which the Bridge Creek flora has much in common, but the Bridge Creek flora also contains an eastern element of eight species to which *Osmunda* would be a not unexpected addition.

On account of poor preservation of the tissues it is impossible to compare the specimen in detail with living or fossil species other than to note a general similarity with the cinnamon fern *Osmunda cinnamomea*. However, in the absence of material showing the presence of internal phloem in the vicinity of the branches its identity with this species cannot be more than merely suggested. It is given the name *Osmundites oregonensis* in order that it may be placed on record and that future reference to it may be facilitated. It is hoped that subsequent discoveries will reveal the structure more adequately.

Osmundites oregonensis, sp. nov. — Dichotomously branched stems surrounded by a thick mantle of leaf bases and adventitious roots. Xylem cylinder of 16–20 separate strands surrounding a pith. Outermost petioles of mantle oval, about 7 mm. broad, and each containing a C-shaped xylem strand.

Holotype No. 23389, Univ. Mich. Coll.

II. A FERN PETIOLE FROM THE GREEN RIVER FORMATION

The following description is based upon some silicified petiole fragments which, when first examined, were thought to belong to a monocotyledon, but the lack of vessels, combined with the distribution of the bundles, seems to furnish indisputable evidence that they represent a fern. Cycadaceous affinities are excluded by the absence of centripetal wood in the bundles and by the lack of mucilage canals. The specimens came from the Eocene Green River formation and were collected in the so-called Eden Valley petrified forest, which is located about twenty-six miles east of Farson, Sweetwater County, Wyoming, and about six miles east of the Hay Ranch. This locality has long been famous for its delicately colored agatized limbs, of which large quantities have been removed by gem-stone collectors. It also yields palm trunks and other plant remains. No systematic study, however, of the petrifactions from this place has been made.

The petioles, which range from 12 to 22 mm. in diameter, are rounded or slightly angular, with a broad adaxial furrow (Pl. II, Fig. 1). The outer part consists of a layer of sclerenchyma made up of small, compact, thick-walled fibers, and the interior contains collateral bundles distributed throughout a ground tissue of thin-walled cells and large intercellular spaces (Pl. II, Fig. 2). Each bundle is surrounded by a sheath of fibers several cells in extent, and the fibrous sheaths of the outermost layer of bundles are connected with the external sclerenchyma by a narrow isthmus of fibers. In most bundles the phloem and the accompanying parenchyma have disintegrated and thus have left the xylem somewhat displaced from its original position within the large oval or circular bundle cavity, but the orientation of the xylem and the phloem is usually evident from the position of the protoxylem. Longitudinal sections show that the xylem consists of scalariform tracheids. In some of the bundles there is evidence of a thin-walled endodermis inside the sclerenchymatous sheath.

The bundles are distributed according to a definite plan, although partial disintegration of the tissues in parts of all sections that have been examined interfered with the determination of the arrangement. Moreover, the arrangement is not identical in any two specimens, although there is evidence that the differences are merely

modifications of one type. In the large leaf stalks, where there are two hundred or more bundles, the arrangement is more complex than that in the smaller ones with fewer bundles.

Extending across the bottom of the petiole section and up both sides is the peripheral bundle layer, in which the phloem is toward the outside and the xylem to the inside (Fig. 1A, *d*). At its upper

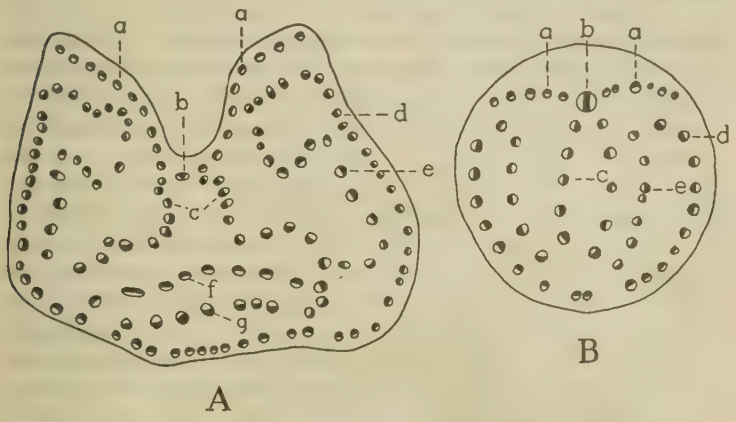

Fig. 1. Diagrams, A and B, showing the bundle distribution in *Eorhachis lomarioides* and *Blechnum zamioides*, respectively. The lower-case letters identify similar structures in each: *a*, adaxial segments with outwardly directed xylem; *b*, double bundle; *c*, internal bundle bands flanking median line of petiole; *d*, peripheral bundle band; *e*, inward extension; *f*, *g*, internal bundle bands. A, tracing from original; B, after Thomae

extremities the ends of the bundle bands turn inward, and they extend downward as bands internal to the outer layer with the phloem and xylem oriented in the opposite direction (Fig. 1A, *e*). Extending across the top of the petiole section is another band (Fig. 1A, *a*) of bundles in which the xylem is toward the outside. At the mid-point of this band (Fig. 1A, *b*) there is a double bundle from which two bands of bundles extend deep into the interior of the petiole (Fig. 1A, *c*) on opposite sides of the median line. The arrangement from here on is slightly uncertain, but these median bands appear ultimately, after undergoing a few minor folds, to connect with the infolds of the lateral peripheral bands just described.

Among living ferns *Blechnum zamioides* shows a bundle pattern

in the petiole that is apparently a modification of the same arrangement (Thomae, 24, Pl. VI, Fig. 2*a*). The Recent and the fossil petioles agree in having a transverse adaxial bundle band in which the xylem is turned toward the outside. Then from the double median bundle (Fig. 1B, *b*) two bands extend into the interior. Thomae interprets the bundle complex in *B. zamioides* as having been derived from two strands arranged in an arc, but with the sides infolded in such a manner as to resemble two figure 5's with one turned to face the other (Fig. 2). The halves of the transverse adaxial band consist of two side segments connected at the median line of the petiole by a double bundle (Fig. 1B, *b*). These are continuous with the deeply infolded bands which loop downward and then upward in the interior and finally extend along the periphery, terminating at the abaxial side of the petiole at the median line (Fig. 1B, *c*, *d*, *e*). The pattern in the fossil form is believed to be similar to this in several respects at least, although it may be somewhat modified. At the bottom of the section and extending crosswise to the median vertical line there are two bands arranged in a flat transverse oval which represent either additional bands or branches from the two lateral ones (Fig. 1A, *f*, *g*). The former of these alternatives seems more probable.

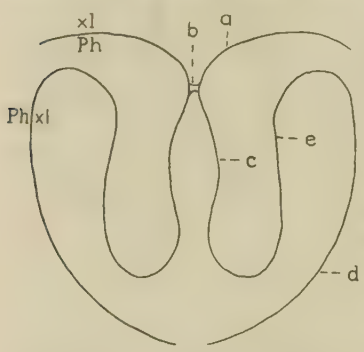

FIG. 2. Diagram showing the form of the bundle bands in *Blechnum zamioides* as described by Thomae. *xl*, xylem; *ph*, phloem. Other lettering as in Figures 1A and 1B

The resemblances noted between the fossil petiole and that of *Blechnum zamioides* would suggest relationship with the Aspleniaceae. It should be mentioned, however, that very little information is available concerning *B. zamioides*. It is not listed by Christensen in his *Index Filicum*, and Thomae states that the structure deviates considerably from that of other and more typical members of the genus. Therefore, since the Recent fern which most closely resembles the fossil is apparently atypical of the genus to which it belongs, and is little known, the exact relationships of the fossil are dubious, and

the suggested affinity with the Aspleniaceae rests only upon such interpretations of the bundle distribution as are possible from the material at hand and the resemblances to Thomae's figure of *B. zamioides*. Resemblances of a still remoter nature may also exist among certain members of the Polypodiaceae, and the structure of the ground tissue also compares with that of *Ceratopteris* of the Parkeriaceae. There is little or nothing to invite comparison with the Cyatheaceae or the Marattiaceae. In the former the numerous bundles of the petiole are arranged in an upper and a lower series, with the phloem of the upper series to the outside, and in those of the Marattiaceae that may be compared (as in *Angiopteris*) there is an evident cyclic arrangement.

Blechnum zamioides belongs to the subgenus *Lomaria*, which is distributed at present throughout the East Indies, Australasia, and Madagascar. No members of the genus *Blechnum* have so far been reported from the Green River formation, and the only representative in it of the Aspleniaceae is *Asplenium eoligniticum*. In fact, only seven ferns have been identified from the entire Green River formation (Brown, 6). Considering the warm-temperate nature of the Green River flora it is only to be expected that it will ultimately be found to contain additional fern types, especially those which at present do not exist so far north.

The fern represented here evidently was a water plant or one which was rooted in very wet soil. Apparently it bore fairly large fronds, as is indicated by the amount of sclerenchyma present, and in habit it might have resembled some of the Recent species of *Blechnum* which are small tree ferns. In view of the uncertainties concerning relationships it seems advisable not to refer this plant to any genus of Recent ferns, but to follow the established practice in paleobotany of creating form genera for such remains. The generic epithet *Eorhachis* is therefore proposed for this ancient fern petiole of uncertain affinity.

Eorhachis lomarioides, gen. et sp. nov. — Fernlike petiole, rounded or angular in cross section, with a broad adaxial groove or concavity; 10–22 or more mm. in diameter; bundles numerous, collateral, surrounded by sclerenchymatous sheath, and arranged in two or more series, which are probably derived from solid strands arranged in an arc; peripheral bundles normally oriented, those of adaxial band reversed; supported externally by a thin layer of sclerenchyma;

ground tissue with numerous intercellular spaces suggestive of an aquatic habit.

Holotype No. 23390; paratypes Nos. 23391–23395, Univ. Mich. Coll.

III. A TREE FERN FROM SOUTHERN TEXAS

In 1934 Miss Elzada Clover and Mrs. Eleanor Cook Beard secured several silicified tree-fern specimens from a locality about ten miles north of Roma, Starr County, Texas. The exact place is not on record, but the probabilities are that the stems came from the Fayette formation of the lower Upper Eocene. There is also a chance that they came from the underlying Yegua formation (also known as the Cockfield), which has yielded plant remains, including silicified palm trunks (Berry, 3; Sellards and others, 18), but in his account of the Cenozoic geology of the lower Rio Grande valley Trowbridge (25) makes numerous references to silicified wood in the basal part of the Fayette. According to the geological map accompanying Trowbridge's paper, a considerable area extending to within a short distance north of Roma is covered by the Fayette formation, with the Yegua outcropping a short distance to the west. The Fayette lies conformably upon the Yegua, and Berry (3) believes that part of what is commonly regarded as Yegua may belong to the overlying formation. So even though the exact stratigraphic position of the rocks from which the fern material came may be in doubt, it is either upper Middle Eocene or lower Upper Eocene, probably the latter.

The specimens are of small trunks ranging from 5 to 10 or more cm. in diameter. The surface is uneven because of the projecting leaf bases, which form a mantle over the stem (Pl. III, Fig. 1). The leaves did not become detached by any normal shedding process, and they remained in place until removed by decay or abrasion. The leaf bases are arranged in a close spiral and project from the stem at an angle of about 45 degrees. In a cross section about twelve leaf bases may be seen in various stages of departure (Pl. IV, Fig. 1; Text Fig. 3). The higher ones show only as outward bulges of the solenostele, whereas the lower ones may be almost detached. The free portions of the petioles are 2 cm. or less in diameter.

Covering the surface of the stem between the leaf bases is a ramentum of flattened, overlapping multicellular hairs which vary from 1 to 2 mm. in width and up to 1 cm. in length. In cross section

they are spindle-shaped and eight to twelve cells thick along the middle portion (Pl. VI, Fig. 3). The light-colored interior of the hair is surrounded by a darker layer three or more cells in depth. The cell walls throughout the hair are thick, which probably made them stiff and bristle-like. The significance of these hairs with respect to the relationships of the plant is discussed later.

ANATOMY

The stems are thoroughly silicified, and in most specimens only the gross anatomical features are visible. In only a few is preservation such that minute details can be satisfactorily studied. Unweathered broken or cut surfaces have a brownish color, which is often quite patchy and uneven, with the result that it is difficult to obtain good photographs of some of the structures. It was impossible to prepare satisfactory cellulose peels, but petrotome sections of some of the specimens show details well if ground sufficiently thin. Smoothly ground surfaces covered with a thin solution of isobutyl methacrylate in xylol and allowed to dry were sufficient in nearly all instances to show everything except the most minute structural details. Such preparations were especially useful in examining large surfaces, and with reflected light it was even possible to see considerable detail under the low power of the compound microscope. They could be very satisfactorily studied with the Greenough-type binocular microscope.

In cross section the outline of the trunks is irregular because of the unevenly projecting but closely spaced leaf bases (Pl. IV, Fig. 2). Very little is known of the epidermis or the thin cortical layer other than the mere fact that they are present beneath the ramentum. The surface covered by the ramentum is very small because of the size and close proximity of the leaf bases, and as a result of the leaf-base mantle and the ramentum no part of the stem surface was exposed.

Only a few millimeters inside the surface to which the mantle and ramentum are attached is a deeply fluted irregular solenostele, the continuity of which is rarely if at all interrupted by leaf gaps (Pl. IV, Fig. 1; Text Fig. 3). The xylem of the solenostele shows on the smooth polished surfaces as a light band 1 mm. or less in thickness, but flanking it on both sides is a sclerenchymatous layer of about equal thickness (Pl. VI, Fig. 2). The thin phloem which

originally accompanied the xylem on both sides is not preserved, and the space is filled with disorganized material. The xylem consists of angular scalariform tracheids which, however, are seldom cut crosswise in a transverse section. Instead of extending vertically,

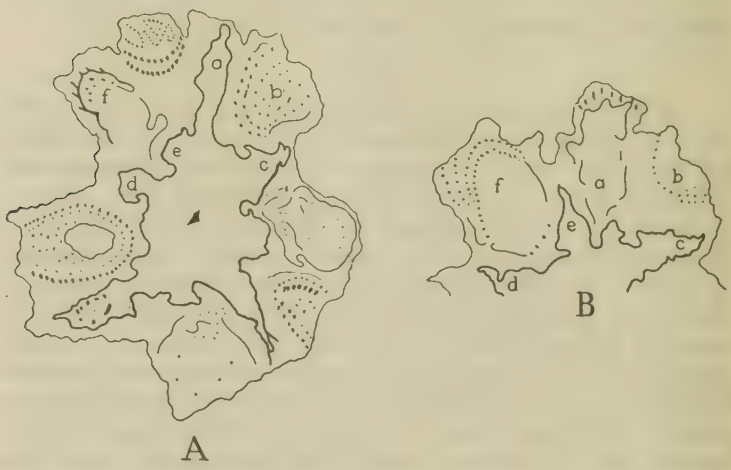

FIG. 3. Cross section at two levels showing the change in configuration of the solenostele within a distance of 6 mm. Comparable structures are shown by letters *a–f*. It will be noted that in B the outward extension of the solenostele shown at *a* in A has become completely detached and the leaf gap has closed within the short distance separating the two sections. The outlines of the stem and the meristele are as accurate as it is possible to trace them. The number and distribution of the bundles in the leaf bases are only approximate, and the medullary bundles are omitted

they often lie transversely or at an angle, or, as may be seen at numerous places, they appear much contorted and follow an irregular course. This irregularity, however, is due in part to the course of the xylem itself. Lengthwise sections show that the vertical course of the xylem is irregular, with frequent bends that often reverse the direction of the layer for short distances. Consequently, sections cut transversely to the axis never pass through all parts of the xylem at right angles to its up-and-down direction.

Owing to the general state of preservation structural details of the xylem are difficult to observe, but there is no reason to believe that it differs markedly from ordinary fern xylem. It consists mostly

of scalariform tracheids with but little intermixed parenchyma. The protoxylem has not been identified (Pl. VI, Fig. 4).

The pith, or that part enclosed by the solenostele, contains numerous medullary bundles, often so closely packed that little or no space remains for typical pith tissue. No attempt was made to form even an approximate idea of the number of these medullary bundles, but they can probably be counted by hundreds. Only a very few instances have been observed of a direct connection between the medullary bundles and the solenostele, so that the relation between these two parts of the stelar system is unknown. Those toward the center of the pith tend, however, to be more irregular in size and shape than those near the periphery and to branch more frequently. Also, they do not all follow a vertical course, but many of them extend crosswise or bend in various ways. The outermost ones are more rounded in cross section and follow a more vertical direction. This slight difference in bundle structure in the inner and outer parts of the pith is suggestive of a modified polycyclic condition, although there is no strong evidence to support this interpretation. It does not seem likely, however, that such an elaborate system of medullary bundles as is seen here is related entirely to the solenostele. Numerous medullary bundles pass outward through the foliar portholes from the pith region into the petioles, each receiving nearly a hundred strands (Pl. V, Fig. 1). At the petiole base these strands are embraced within the hollow of the gutter-like trace, and farther out they are still partly surrounded by the separate strands into which the trace becomes divided. They remain readily distinguishable from the trace strands by their smaller size.

The medullary bundles are approximately 0.5 mm. in diameter (Pl. VI, Fig. 1). In most of them the xylem is not preserved, and only the thick sclerenchymatous sheath surrounding each one is left.

The continuity of the solenostele and the seeming absence of leaf gaps in the transverse section of the stem is one of its distinctive and most interesting features. It has been possible by means of a series of slices cut transversely to the petioles but oblique to the transverse plane of the stem to follow the course of the vascular supply of the petiole from the points of its inception to the nearly complete leaf stalk (Fig. 4). The petiole bases are too short to show satisfactorily the arrangement of the tissues in the free petiole, but it appears that the trace supply beyond the leaf-base mantle consists

of separate circular or nearly circular bundles concentrically arranged in two or more cycles (Pl. IV, Fig. 2). These bundles, as will be subsequently shown, originate from two sources.

At the point where the vascular supply of the petiole becomes entirely free from the stem the leaf-trace complex contains, along with other strands to be described later, a trough-shaped strand about twice as wide as deep, with inturned upper margins (Fig. 4*e*). The first indication of the formation of this strand from the solenostele is an outward bulge which, when followed upward, elongates rapidly into a slender tonguelike projection (Fig. 3 at *e*). Before it breaks into separate strands it becomes rather long (Fig. 3 at *a*; Pl. V, Fig. 1). It is evident that the passageway from the medullary region into this tonguelike loop is the morphological equivalent of the leaf gap, but since the opening through the solenostele closes at a level no higher than the acropetal margins of the trough, and since the trough at this level has not yet broken into separate strands, no break is visible in the continuity of the solenostele within a transverse section. A solenostelic instead of a meristelic condition results, therefore, from the abrupt closure of the leaf gap above the point of trace departure. The gap, however, is present in a morphological sense, but it passes obliquely from the pith into the leaf base.

The abrupt closure of the leaf gap produces marked changes in the configuration of the solenostele within very short distances. In one instance (as may be seen in comparing Figs. 3*a* and 3*b*) a complete transition from the long tonguelike projection along the abaxial margin of the trace to the point where detachment was complete took place within a vertical distance of 6 mm. Just above the closed gap the solenostele bends rather abruptly inward (as shown in Fig. 3*b* just below the letter *a*, and at two points in the upper and lower parts of Pl. IV, Fig. 2).

In two or more places where it was possible to follow the changes in the outline of the solenostele from the bottom to the top of the gap a short "compensation tongue" was found to join the lateral margins of the solenostele at the point where the gap would be expected to continue above the acropetal margins of the trace strand (Pl. V, Fig. 2; Text Fig. 4*a*). This short downwardly projecting flap of the solenostele appears to be mainly responsible for the closing of the upper part of the gap (Fig. 4*b*), where it would otherwise occur and cause a break in the continuity of the stele in cross section.

Downward, the tongue narrows abruptly, and within a distance of 2 or 3 mm., or at about the median level of the departing trace, it loses itself among the medullary strands (Pl. V, Fig. 1). Before the

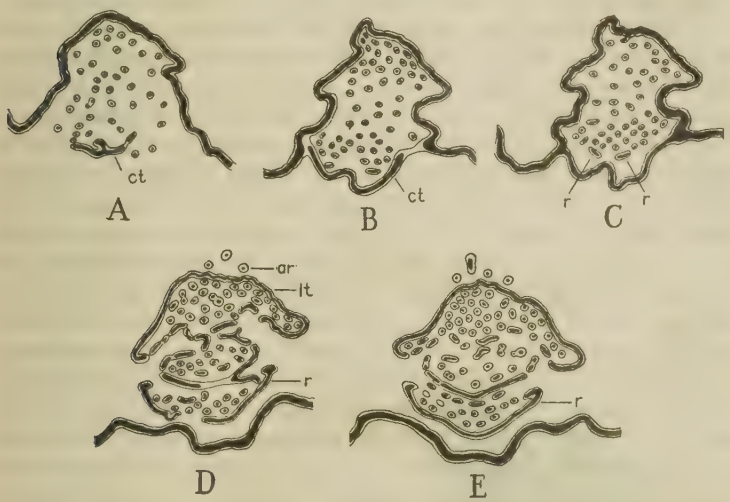

FIG. 4. Camera-lucida tracings of a series of sections showing the development of the leaf trace supply and the closing of the gap by the "compensation tongue," beginning with the lowest: A, section showing the outward bend of the solenostele along the lower abaxial side of the petiole base. The compensation tongue is shown at *ct*, and at B it has broadened until it has closed off the leaf gap. The sclerenchymatous sheath is continuous, but the xylem (in black) has not yet joined the solenostele. The vertical interval between A and B is 4.5 mm. At C the closure of the gap is complete, and two medullary bundles, *r*, have broadened slightly preparatory to forming the "roof." The vertical interval between B and C is 1 mm. At D the trough-shaped leaf-trace strand, *lt*, has become completely separated from the solenostele, and three adventitious roots, *ar*, have departed from the outer surface. The roof strands have continued to widen and are partly joined. The vertical interval between C and D is 4 mm. Section E is 1 mm. above D and shows the form of the trough-shaped leaf trace with its inturned margins and the two curved strands of the roof *r*. All × 3

tongue becomes detached from the solenostele it is easily distinguishable as the inward bend previously mentioned (Pl. V, Figs. 3–4). This compensation tongue seems to be similar to that described by Tansley (23) in *Matonia pectinata* and by Bower (4) in *Thyrsopteris elegans*. In both these ferns the compensation tongue closes the leaf

gap and forms a continuous unbroken solenostele. A continuous solenostele has also been observed in a few other ferns, including *Pteris alata* var. *Karsteniana* and *Dicksonia adiantoides* (Gwynne-Vaughan, 11), but in them the closure is due to a very low leaf gap.

When cross sections of the petiole bases are examined other structures are visible in addition to the trough-shaped strand and the accompanying medullary strands. Lying above the trough and covering the central part like a roof are one or two additional transversely broadened strands which somewhat resemble the lower strand except that it is slightly shorter and less curved. They are inverted with respect to the lower strand (Fig. 4*e*), with their concave sides downward (uppermost in the figure). At first the origin of these "roof" strands was a mystery because at no place could they be seen attached to or in any way connected with the solenostele, and they are not present over the main trace strand at the level where the compensation tongue closes the gap. However, upon examination of carefully cut oblique sections, it was found that this "roof" originates by the broadening and lateral joining of two or more medullary strands which enter the leaf gap immediately dorsal to the compensation tongue (Fig. 4*c–e*). The entire leaf-trace supply consists, therefore, of tissue derived from both the solenostele and the medullary bundle system.

Small adventitious roots spring from the abaxial side of the petiole base (Fig. 4*d–e*).

AFFINITIES

The affinities of this plant are believed to be with the Cyatheaceae, the family which includes the majority of the living tree ferns. The most obvious cyatheoid features are the arborescent habit and the general plan of the vascular system. It differs from the more typical members of the family in having an unbroken solenostele. In most species the continuity of the stele is broken at the places where the leaf traces depart by rather wide gaps, and thus separate the vascular ring into meristeles. The difference between these two so-called stelar types is, however, merely a matter of the vertical extent of the leaf gaps and is therefore not a fundamental one, even though the aspect produced by the two in cross section is quite different.

In comparing the fossil fern with living members of the Cyatheaceae the problem is rendered difficult because of our ignorance

of the vascular anatomy of many tree ferns growing at present in the Western Hemisphere. The locality from which the material came is only a few hundred miles north of the present range of tree ferns in Mexico, and it is possible that the living equivalents of the Eocene fern may still thrive among the numerous species of the Cyatheaceae now growing in Mexico or Central America. Until these living ferns are made the subject of a comprehensive anatomical study, it is futile to speculate at length upon this possibility. The most extensive anatomical study of tree ferns made within recent years is by Ogura (14), who gives a detailed account of the eight species found in Japan and Formosa. All the species treated by him have distinct leaf gaps and therefore lack the feature most prominently displayed in our form.

The Cyatheaceae are divided by most authors into three tribes, the Dicksonieae, the Thyrsopterideae, and the Cyatheeae. The fossil apparently does not belong exclusively to any of these tribes, but shows instead characteristics common to all three. Considering first the Dicksonieae, we find in *Cibotium Barometz* a leaf trace which begins as a single gutter-shaped strand with deep lateral folds, but soon breaks into separate bundles. *C. Barometz*, however, has a creeping rhizome, although other members of the genus (as well as the Dicksonieae in general) are upright. Most members of the Dicksonieae lack medullary bundles, although occasionally, as in *Dicksonia rubiginosa*, internal thickenings of the solenostele may become detached and form internal strands in the internodes (Gwynne-Vaughan, 11).

The Thyrsopterideae contain one species, *Thyrsopteris elegans*, which is restricted in its present natural haunts to the island of Juan Fernandez. Probably the foremost point in common between this fern and the fossil is the compensation tongue, already mentioned, which closes the leaf gap above the departing trace, although this structure is present also in *Matonia pectinata* of the Matoniaceae. In *Thyrsopteris* the leaf trace departs from the solenostele as a continuous wavy band, but the sclerenchymatous sheath usually present in the cyatheoids is lacking.

The third tribe, the Cyatheeae, contains three genera, *Alsophila*, *Hemitelia*, and *Cyathea*, all of which are typically meristelic with medullary strands and leaf traces divided into numerous bundles from the place of their origin. In *Alsophila pruinata*, however, the

trace is a horseshoe-shaped band more like that of *Cibotium Barometz*, *Thyrsopteris elegans*, and the Eocene form. Although *A. pruinata* is described as siphonostelic (solenostelic), the condition is the result of long internodes and not of small gaps. The solenostelic condition in *A. pruinata* and the fossil species is, therefore, fundamentally different, and does not furnish a satisfactory basis for comparison.

Concerning the phylogenetic significance of the composite character of this fern, the offhand proposal might be proffered that it is a generalized ancestral type from which the Recent tribes have become segregated. This, however, does not seem as probable as an alternate one that it represents a separate line. In accepting the first hypothesis it becomes necessary to assume that the Recent tribes owe some of their differences to the loss of certain distinctive anatomical features. For example, the Dicksonieae would have lost most of the medullary strand complex and the compensation tongue, the Thyrsopterideae would have retained the latter structure but lost the sclerenchyma, and the Cyatheeae would have lost the compensation tongue and the solid trace strand. It is hardly possible that the medullary strand system, including the compensation tongue, is a primitive feature, so that, with the exception of the troughlike trace strand (which is primitive), the Texas fern probably represents a condition of development about as advanced as any of the living members of the Cyatheaceae. There is no evidence that any of the tribes of the Cyatheaceae originated from ancestors more structurally complex. The original type was probably a simple form not embodying so many seemingly advanced features as are found here.

Although the fossil reveals a combination of tribal characters, it is believed that the sum total of its features indicates a place between the Thyrsopterideae and the Cyatheeae. This view, nevertheless, is subject to future modification since it is based mostly upon the well-developed system of medullary bundles, the sclerenchymatous sheath, the trough-shaped leaf-trace strand, and the compensation tongue. Were it not for the compensation tongue this same set of characters would point toward the Dicksonieae instead of the Thyrsopterideae, because in the latter tribe the sclerenchyma is lacking. So it is a matter of choosing between the compensation tongue and the sclerenchyma as a criterion of affinity, and the view is taken that structures in the vascular system should be selected as having more fundamental phylogenetic meaning than extravascular tissues.

Little may be said by way of comparison with any particular genus of the Cyatheeae. The three genera *Alsophila, Hemitelia*, and *Cyathea* are separated solely on the basis of whether the indusium is absent, partial, or complete, and from the purely anatomical standpoint they are indistinguishable as at present defined.

COMPARISONS WITH OTHER FOSSIL FERNS

Because of the widespread practice of comparing with Recent genera compressions of the sterile foliage of fossil ferns in which fructifications or other evidences of affinity are lacking, the early history of the Cyatheaceae is veiled in the same uncertainty that surrounds most of the other fern families. Plants from rocks as ancient as the Culm (equivalent to Lower Carboniferous or Mississippian) have been assigned to the Cyatheaceae, although on evidence that is not satisfactory. Our knowledge of the family properly begins with the late Triassic or Jurassic, in which several frond types bearing cyatheoid fructifications are known. Remains of stems showing either surface features or internal structure resembling the Cyatheaceae appear rather abundantly in the Wealden (basal Lower Cretaceous) of Europe. This shows that the family was more widely distributed in the past than it is now. Up to the present no petrified cyatheoid stems have been reported from North America, and the fossil record of the family consists of a few foliar remains ranging from the Triassic to the Eocene. At no time do the Cyatheaceae ever appear to have been abundant in North America, and it is noteworthy that in the large Wilcox flora of Eocene age they have not been recognized. The Eocene probably marks their last stand north of Mexico, and as the tropical Eocene climates gave way to more temperate conditions the tree ferns retreated southward along with the palms and other tropical plants.

Because soral and sporangial differences are employed much more generally than anatomical characteristics in distinguishing the genera of living ferns, it is frequently impossible to assign fossil stems in these genera, even though the relationships may be obvious. It is therefore often necessary to give special generic names to fossil forms. In the Cyatheaceae the three genera *Alsophila, Hemitelia*, and *Cyathea* do not show anatomical differences that correspond to differences in the indusium; hence fossil stems resembling any of these must be placed in separate groups. The literature contains a

number of generic names that have been applied to fossils believed to represent the Cyatheaceae, some of which are *Alsophilina*, *Oncopteris*, *Cyathocaulis*, *Cebotiocaulis*, *Caulopteris*, *Protopteris*, and *Dendropteridium*. *Alsophilina* and *Oncopteris* were originally applied to surface impressions and, therefore, are not suitable for structurally preserved material. *Caulopteris*, also an impression, is used mostly for Carboniferous stems known to possess the internal structure of *Psaronius*. The remaining names, *Cyathocaulis*, *Cebotiocaulis*, *Protopteris*, and *Dendropteridium*, embrace the majority if not all of the known petrified cyatheaceous stems of all ages. *Protopteris*, the first to be proposed (Presl, in Sternberg, 22), refers to stems of tree ferns in which the petiole scar bears a horseshoe-shaped leaf-trace imprint indented at the sides. The leaf bases are spirally arranged about a central axis which contains bandlike vascular bundles, usually in the form of meristeles. Seward (19) provisionally places *Protopteris* in the Cyatheaceae because of its resemblance to *Dicksonia antarctica*. Its several species are confined mainly to the Lower Cretaceous.

Cyathocaulis and *Cebotiocaulis* were described by Ogura (15) from the Upper Jurassic and Cretaceous of Japan. Both these genera have large leaf gaps, curved ribbon-like meristeles, and medullary bundles. The names are given apparently in allusion to the similarities of the leaf traces to those of *Cyathea* and *Cebotium*, respectively, but as pointed out by Bancroft (2), they differ from these genera in having medullary roots and inturned meristele margins. *Cebotiocaulis* differs further from *Cebotium* in its medullary bundles. On the other hand, there is little question that they both belong to the Cyatheaceae, and probably to the tribe Cyatheae. Ogura's genera contain but one species each, *Cyathocaulis naktongensis* and *Cebotiocaulis Tateiwae*. *Dendropteridium*, also having but one species, *D. cyathcoides*, was described by Bancroft (2) from the Tertiary of East Africa. The specimen described is typically cyatheaceous with medullary bundles, curved meristeles, large leaf gaps, and separate trace strands. *Dendropteridium* is proposed as a form genus "for fossil fern stems of dendroid dimensions, of which, in the absence of associated vegetative and reproductive material, the exact affinities are unknown" (2, p. 251).

Of the four genera of fossil ferns described above (*Protopteris*, *Cyathocaulis*, *Cebotiocaulis*, and *Dendropteridium*) none are acceptable for the fern described here. It may resemble *Protopteris* in several

respects, but this genus is generally used for stems which show the horseshoe-shaped trace strand on the surface, and this feature has been stressed by most authors (for example, by Corda, 9, and Seward, 19, 20). There are differences of opinion, however, regarding the taxonomic value of the shape of the trace scar, but since it always enters into specific descriptions and since some species are based almost entirely upon it, the writer does not deem it advisable to use the name *Protopteris* for specimens in which the trace scar does not show at all on the surface. Moreover, little is known about the anatomy of *Protopteris*. Corda (9), Seward (19, 20), and others have shown that the distribution of the vascular strands is similar to that of the Dicksonieae, but, lacking details, the published figures are insufficient for accurate comparisons. Of course, some degree of relationship between our fern and *Protopteris* is possible in view of the trough-shaped trace strand, which both have in common with the Dicksonieae and the Thyrsopterideae. But, as has been shown, the trace supply of the Texas fern is complicated and consists of strands derived from the medullary system as well as from the solenostele.

There is little in the structure of *Cyathocaulis* that draws comparison other than its general cyatheoid features. It has a system of medullary bundles, but it differs in being meristelic and in having large leaf gaps and separate trace strands. *Cebotiocaulis* is similarly removed from our fern, although the leaf trace does arise as a continuous band, which soon breaks up into separate bundles, and the petiole bases adhere to the stem surface.

As previously explained, the genus *Dendropteridium* was proposed for fossil tree-fern stems the affinities of which are in doubt because of the absence of associated diagnostic vegetative or reproductive parts. Of the four fossil genera under consideration this one is probably the most suitable for the reception of the Texas fern, although it is not an entirely appropriate one. *Dendropteridium* was proposed as a form genus, and apparently was intended for any structurally preserved tree fern that could not be assigned elsewhere. But in our fern the cyatheaceous affinities are hardly to be questioned; hence it should not be placed within a genus which in the future may receive forms not related to the Cyatheaceae. The problem of generic or tribal relationships of our fern arises not only from a lack of associated fronds and fructifications, but also from its peculiar ana-

tomical structure, and to assign it to a form genus such as *Dendropteridium* would be to ignore the value of the anatomical features in its classification. Furthermore, placing it in *Dendropteridium* would be making it congeneric with another species which we know is different; hence the assignment would be entirely arbitrary. The only logical or satisfactory procedure, it seems, is to place the Texas fern within a genus of its own. An alternative would be to amend the genus *Protopteris* (which it resembles more closely than *Protopteridium*) so as to include it, but this should not be done solely on the basis of the published descriptions. It would be necessary to examine some of the original material and to elucidate the anatomical structure more completely.

Since no previously described genus, either living or fossil, seems appropriate for the reception of the Texas tree fern, the name *Cyathodendron* is proposed for it. The diagnosis is as follows.

Cyathodendron texanum, gen. et sp. nov. — Stems upright, covered with a mantle of spirally arranged leaf bases and flattened multicellular hairs; vascular system a solenostele accompanied by numerous medullary bundles; all vascular parts surrounded by sclerenchyma; solenostele continuous; leaf gaps small and closed above departing trace by a compensation tongue; leaf-trace supply of numerous strands and derived from solenostele and medullary system; solenostelic trace strand a continuous trough-shaped band with incurved margins, and above this, in inverted position, one or two similar bands formed by fusion of medullary strands passing into the petiole; numerous single medullary strands also present in petiole; adventitious roots arising from abaxial surface of petiole base.

Holotype No. 23405; paratypes Nos. 23406–23407, Univ. Mich. Coll.

IV. THE GENUS *TEMPSKYA* CORDA

Recent investigations have shown that the Mesozoic fern genus *Tempskya* is widely distributed in the western part of the United States, especially in the middle and northern Rocky Mountain regions, and further investigations will probably reveal a still wider range. It seems rather strange that this distinctive plant should have remained so long in a state of relative obscurity, because well-preserved specimens have reposed in both privately owned collections

and in public museums for many years. The probable reason that *Tempskya* has only recently received a share of the attention it deserves is that its silicified false stems bear a superficial resemblance to masses of fossil palm roots, and many have been so identified. Preservation is often such that the real nature of the remains is not evident without thin sections, unless one happens to be on the lookout for it. In some localities, notably at Greenhorn, Oregon, the material is attractively colored and is eagerly sought by amateur collectors as an inexpensive gem stone.

The first description of a *Tempskya* from western North America is Seward's account of *T. Knowltoni* (Seward, 21), from Wheatland County, Montana. Nothing more was added to our knowledge of the genus until 1936, when Brown (7) published a short paper in which he set forth its gross distinguishing characters. The macroscopic differences between *Tempskya*, *Palmoxylon*, *Psaronius*, and the woody tissues of the conifers and dicotyledons are briefly explained. In 1937 Read and Brown (17) gave a detailed account of the anatomy of three species of *Tempskya*, two of which were new. Ten western localities are listed, a synopsis is given of the American species, and the taxonomic relationships and stratigraphic range are discussed. They conclude that the genus ranges throughout the Cretaceous, but that in western North America it appears to be restricted to the Colorado group, which is approximately mid-Cretaceous. The most recent contribution is a short paper by Andrews (1), in which references are made to occurrences of *Tempskya* in western Wyoming and adjacent Utah.

Several specimens of *Tempskya* have lately been added to the fossil plant collection of the Museum of Paleontology of the University of Michigan. Most of the material is from new localities in Montana and Wyoming, although some portions of false stems have been secured from "Locality 11" of Read and Brown (17, p. 125) at Greenhorn, Oregon. They merely mention this material because it was received by them too late to be described in their report.

The essential gross and microscopic characters of *Tempskya* have been described by previous authors, so that they need not be repeated here. The aim of the present account is to place on record two new localities for the occurrence of the genus and to describe two additional species. The author is convinced that the species of *Tempskya* cannot be identified from macroscopic characters alone,

and that microscopic examination is necessary. Accurate identification is therefore contingent upon satisfactory preservation, and for the more poorly preserved material it may become necessary to establish "form species" based upon the grosser aspects.

Tempskya Wesselii, sp. nov. — This species is named in recognition of the late Mr. Louis Wessel, of Great Falls, Montana, who furnished the specimen that is here designated the holotype. According to information furnished by him, it came from the Kootenai formation of the "bad lands" northwest of Great Falls. In this region, however, the Kootenai is overlain by the Colorado group, and since elsewhere in western North America *Tempskya* is known only from the Colorado group, it is possible that this material had weathered out of the higher beds. Mr. Wessel stated explicitly, however, that the material is from the Kootenai, and that it was all found within a vertical interval of about three hundred feet.

To this species is assigned the jasperized material of *Tempskya* from the placer outwash at Greenhorn, Oregon (Pl. VII, Figs. 1–2). Although more abundant than the material from Great Falls, it is less well preserved, so that it is considered advisable to designate as the holotype the specimen showing the best tissue preservation. The following diagnosis is based upon the holotype.

False stems radially symmetrical; individual stems 4–5 mm. in diameter, internodes long, usually showing only one leaf trace in a transverse section; cortex distinctly three-layered; outer layer of thin-walled slightly flattened cells with dark contents, constituting about one fourth of the cortical zone; middle layer slightly thicker, fibrous; inner layer about equal in extent to the middle layer, cells thin-walled, oval, with dark contents and often showing an imperfect radial alignment, the layer containing on the outside a continuous band and on the inside a discontinuous band of stone cells; outer endodermis present; pericycle and phloem thin (seldom preserved); xylem with considerable interspersed parenchyma; inner endodermis present; pith sclerenchymatous in center, outer parenchyma layer thin.

Holotype No. 23399; paratypes Nos. 23398, 23401, Univ. Mich. Coll.

Owing to the radial construction of the false stem and the complex structure of the cortex, *Tempskya Wesselii* obviously belongs to the *grandis-Rossica* group of *Tempskya* as outlined by Read and Brown

(17, p. 119). It differs from the species they placed in this group, however, in having smaller stems and longer internodes, and from *T. grandis* in particular in having two bands of stone cells in the inner cortex. This last character is believed sufficient to justify placing the material in a new species. With respect to size of stems and length of internodes some resemblance to *T. Knowltoni* and *T. minor* may be noted, but these species lack the stone cells in the inner cortex, and the arrangement of the stems is such as to indicate that the false stems grew in a dorsiventral position (Read and Brown, 17). It is apparent from the combination of characteristics present in *T. Wesselii* that stem size and length of internodes are not always linked with the habit of the false stem. As yet we know of no species with large stems and short internodes that have the dorsiventral habit. The dorsiventral forms, on the other hand, may all have small stems, although small stems are not confined to this group.

In view of the fact that the main distinguishing feature of *Tempskya Wesselii* is the double layer of stone cells in the inner cortex, this tissue will be described in some detail (Pl. IX, Figs. 1–2). The whole inner cortex is about one third of a millimeter in extent, although it varies somewhat in different stems and in different parts of the same stem. The outermost sclerenchyma layer is a thin, somewhat irregular band generally not exceeding three or four cells in breadth, which appears to lie along the transition zone between the middle and the inner cortical layers. Whether it belongs to the middle or the inner cortex is not absolutely clear, but the assumption is that it belongs to the inner zone (Pl. IX, Fig. 2). The cells are fairly large and angular and have thick walls and small lumina. Read and Brown refer to them as "gummy sclerenchyma," apparently because of their homogeneous appearance where they are not well preserved and the brownish color of the walls. However, when specimens are examined carefully in thin section, numerous canal-like pits may be seen penetrating the thick walls, indicating that these cells are true stone cells, although in the less well-preserved ones partial disintegration of the wall gives the appearance of a gummy substance. The cells of the inner sclerenchyma layer resemble the outer ones except that they form a band of cell clusters which are isolated from one another by a distance about equal to or slightly less than their own diameter. A peculiarity in the chemical make-up of these stone cells is that in sections prepared by the

"peel" method they are not recognizable, which indicates that they are soluble in the hydrofluoric acid used in the etching process. Consequently, if only peel sections were studied, this species would not show its main distinguishing feature.

Between the two stony layers of the inner cortex is a homogeneous tissue of rounded or oval thin-walled cells with dark foamy contents (Pl. IX, Fig. 2). They vary somewhat in size and tend to be flattened against one another in radial rows. Between cells of adjacent rows there are numerous rather large intercellular spaces.

The inner cortex is succeeded on the inside by the outer endodermis, which in places is well preserved as a single layer of small thin-walled cells with dark contents. Between the endodermis and the xylem is a zone of thin-walled cells which represents the pericycle and phloem, but these tissues cannot be distinguished from each other.

In the stems of the holotype specimen most of the xylem has disappeared, the space having become filled with clear silica (Pl. VIII, Fig. 1; Pl. IX, Fig. 1). The disintegration of the xylem is difficult to explain when the excellent preservation of the other tissues is considered. Nevertheless, small portions are present in which the structure is well revealed. One or more parenchyma cells are usually present in contact with each tracheid. These cells are sometimes isolated and in contact with the shorter tracheid walls, although frequently they occur as chains of three or more cells. Read and Brown place some stress on the prevalence of xylem parenchyma in specific diagnoses. *T. grandis* and *T. Rossica*, according to them, contain much xylem parenchyma, whereas in *T. Knowltoni* and *T. minor* there is said to be little or none. It is evident from the material of *Tempskya* available for study that there is some variation in the amount of parenchyma in the different species, but whether this character is one of value in distinguishing between species may, it seems, be questioned unless material of the species concerned is available for direct comparison. Because the parenchyma cells are rather regularly distributed among the tracheids — sometimes singly, sometimes in chains of two, three, or more — it is seldom possible to express the condition in concise terms. This difficulty is illustrated by the statement by Read and Brown that in *T. Knowltoni* the xylem parenchyma is composed "almost entirely of scalariform tracheids with almost no xylem parenchyma." This statement might mean either that parenchyma cells are difficult to find in *T. Knowltoni* or

that the total amount of parenchyma is small because of the smaller size of the cells as compared to the proportion of tracheids making up the tissue. It is obvious, however, that in *T. Knowltoni* parenchyma cells are of frequent occurrence in the xylem, but they are usually isolated cells, or sometimes two cells may occur together. In such species as *T. grandis* and *T. Wesselii* the parenchyma cells may form chains of three or, occasionally, more cells which separate the tracheids, but the continuity of the tracheid tissue is not interrupted to any extent.

Lining the inside of the xylem ring is a narrow zone of thin-walled cells apparently consisting of phloem and pericycle, and this is succeeded by the internal endodermis. The endodermis surrounds the pith, which consists of a narrow outer zone of thin-walled cells enclosing the inner sclerenchymatous part. The thick walls of the sclerenchyma are perforated by numerous burrow-like pits.

The form and departure of the frond traces are identical in all essential respects with those of other species of *Tempskya* (Pl. VIII, Fig. 1). Completely detached petioles are but rarely found in the sections. The xylem arc of the petiole base is a thin broadly horseshoe shaped band slightly flattened abaxially, with the ends slightly enlarged. At this stage they are not curved inwardly, and it seems doubtful that even in the free petiole the extremities become as strongly incurved as those in *T. grandis* and *T. Rossica*, although the exact condition is unknown above the petiole base.

The cortex of the petiole base shows the same structural differentiation as that of the stem, including even the two layers of stone cells in the inner cortex. The outer stony layer is continuous all the way around, but the inner one extends only as far as the xylem arc. No stone cells can be seen along its concave adaxial surface or in the gap between the extremities of the xylem.

The roots of *Tempskya Wesselii* are well preserved and resemble those of *T. grandis*, which are well illustrated by Read and Brown (5, Pl. 41, Fig. 4). The diarch stele is enclosed by a thick sclerenchymatous cortex, which is bounded on the outside by a layer of large-celled parenchyma (Pl. VIII, Fig. 2). This parenchymatous layer seems to vary considerably in extent. In many roots it has been wholly or partly torn away, and the remaining portions are usually crushed. In a few roots, however, the tissue is complete and forms an outer cortical zone about equal in extent to the sclerenchyma.

No filiform root hairs, such as Read and Brown figure in connection with *T. minor*, have been seen in *T. Wesselii*. This outer cortical parenchyma also extends as strips of crumpled tissue into the spaces between the roots and constitutes the binding tissue of the root mass. Apparently, as new roots grew downward among the older roots, they often penetrated this outer layer, and thus pulled it away from the roots to which it had originally been attached and in many instances tore it loose completely. The outer cortex of these younger roots was in turn penetrated by other roots, with the result that very little of it remains in place.

The foregoing interpretation of the binding tissue of the root mass of the false stem seems to be supported in material identified as *Tempskya grandis* from Wheatland County, Montana (Pl. XI, Fig. 2). In this material preservation is superior to that of any other specimen so far observed, and sometimes two or more roots are surrounded by a common layer of parenchyma which has become distended beyond its original limits. These roots also bear root hairs.

Tempskya wyomingensis, sp. nov. (Pl. X; Pl. XI, Fig. 1). — The material assigned to this species consists of several false stem fragments which were found about twenty miles northeast of Greybull, Bighorn County, Wyoming. The area which yielded the remains lies principally within the valley of Beaver Creek, a southerly flowing tributary of Shell Creek. The eastern portion of the Bighorn Basin lying between Sheep Mountain, just north of Greybull, and the Bighorn Range consists of a shallow syncline in which the sediments range from Paleozoic to Cretaceous. The rocks covering most of the syncline belong to the Colorado group, and beneath it are the Cloverly and the Morrison formations. These latter formations outcrop as a narrow band along the eastern margin of the basin, where they were tilted up by the elevation of the Bighorn Range, but in the vicinity of Beaver Creek they are uncovered over a larger area.

Fragments of *Tempskya* are widely scattered within the valley of Beaver Creek and its tributaries, but they are nowhere abundant. They have been found only where the Morrison formation is exposed and are associated with enormous numbers of dinosaur bone fragments and gastroliths; in fact, a few small pieces were found only a mile or two from the quarry of the Sinclair Dinosaur Expedition of 1934 (Brown, 5). Also associated with the fern material are occa-

sional fragments of the trunks of *Cycadeoidea*, which resemble those from the Freezeout Mountain locality north of Medicine Bow.

The author is indebted to Mr. and Mrs. F. W. Dennler, of Greybull, for most of the material of *Tempskya wyomingensis*. Another specimen was submitted by Mr. H. Timmel who, with Mr. Leslie Couch, acted as a guide in the Beaver Creek locality in 1941.

The material is not so well preserved as that of *Tempskya Wesselii*, and some of the histological details admirably displayed by that species are obscure in this one. The xylem cylinder, however, is well preserved, and the false stems had suffered little or no crushing.

Tempskya wyomingensis is very close to *T. grandis*, and specific separation is made only after considerable deliberation. Its diagnosis is as follows:

False stems radially symmetrical; individual stems 6–8 mm. in diameter, internodes short, with 1–4 leaf traces appearing in each transverse section; free phyllopodia frequent; cortex three-layered; inner layer, which constitutes less than one half of the cortical zone, bounded on outside by a narrow but continuous band of stone cells, and on inside by a discontinuous band occupying one half of the width of the layer; endodermis not visible; xylem with considerable interspersed parenchyma, 5–8 cells in extent, and with an almost continuous zone of small tracheids around periphery; inner and outer phloem and pericycle present; pith mostly fibrous; xylem strand of free petioles (phyllopodia) with strongly incurved margins; roots provided with filiform root hairs.

Holotype No. 23400, Univ. Mich. Coll.

As already stated, this species is close to *Tempskya grandis*, and were it not for the double layer of stone cells in the inner cortex (a feature it shares with *T. Wesselii*) it would be placed within that species without hesitation. Its internodes were evidently shorter than those of *T. Wesselii*, but longer than those in *T. grandis*, though it is possible that there was some variability with respect to this feature, as is indicated by the fact that the number of leaf traces per stem section varies from one to three (Pl. XI, Fig. 1). It is difficult to utilize such features as length of the internodes and amount of parenchyma present in the xylem for separating species because of the lack of absolute standards for comparison.

Tempskya wyomingensis agrees with *T. grandis* in the radial construction of the false stems, in having large stems (6–8 mm. in

diameter), in having large petiole bases (four fifths of the diameter of the stem), and in the relatively short internodes. A feature it possesses in common with *T. nitens*, one of the dorsiventral species, is the presence within the root mass of free petioles (Pl. X, Fig. 4; Pl. XI, Fig. 1). These generally lie near the stems. Its point of agreement with *T. Wesselii* is the double layer of stone cells in the inner cortex, but it disagrees markedly in size of stems.

In the preceding descriptions of the two new species of *Tempskya* stress is placed upon characteristics which are believed to distinguish them from previously described species, and no effort is expended in elaborating upon the general morphology of the base stem or the more obvious anatomical structure of the vascular system. These phases have been adequately dealt with by previous authors. The main result of this study has been to give a better idea than we have had before of the variety of structures exhibited within the genus which are believed important in separating species, and also to show that in most instances the species can be identified only upon microscopic examination. The segregation of the species by Read and Brown into two groups — those with radially symmetrical base stems and those with the dorsiventral habit — is believed to be basically sound, but with the addition of two species to the radially symmetrical group this one is now the larger. It appears, however, that the associated characteristics attributed to this group by Read and Brown do not hold because, as shown by *T. Wesselii*, some of its members have small stems with long internodes. Strong adventitia seem to accompany the larger stems.

Aside from stem size and internode length, which are relative characters and cannot be well expressed in definite terms, the most dependable basis for specific separation seems to rest in the structure of the cortex. Two point possibly, *T. Wesselii* and *T. squamigera* all agree in having a three-layered cortex, but the last two are distinguished from the first one by the presence of the double layer of stone cells in the inner zone. *T. Wesselii* and *T. squamigera*, on the other hand, are distinguished from each other by stem size and length of internodes. It is unfortunate that Nathorst and Gwynne-Vaughan (17) failed to give a more complete account of the cortex of *T. Sternbergi*. Not enough is made of sclerenchymatic fibre bundles, although a close inspection of one of their figures (Pl. V, Fig. 4) gives the impression of two relatively large ones such as occur in *T. Wes-*

selii and *T. wyomingensis*. It is impossible, however, to be certain of this because of the low magnification at which the tissues are shown and the rather inferior preservation that is evident.

When describing species of fossil plants one is perpetually confronted with the problem of how much structural variation to permit to enter into the specific diagnosis or how finely to draw specific distinctions. Accordingly, species are narrowly or broadly interpreted. In describing leaf impressions from the Tertiary the amount of variation that may be encompassed within a species may be judged by the range of variation displayed by the nearest living equivalents. The problem is somewhat different with anatomical material because inside the plant body the range of variation is usually considerably less and, moreover, some species are much alike so far as vascular anatomy is concerned. It appears, therefore, that constant anatomical differences, even though they may be slight, indicate distinct species. A case in point is demonstrated by *T. Wesselii* and *T. wyomingensis*, which have the double band of stone cells in the inner cortex. This relatively inconspicuous feature appears constantly throughout the stems of both species, and in the living condition was no doubt accompanied by distinctive features of the fronds or sporangia which set these apart from others.

University of Michigan

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EXPLANATION OF PLATE I

Fig. 1. *Osmundites oregonensis*, sp. nov. Holotype. Slightly enlarged

Fig. 2. Portion of holotype specimen shown in Figure 1, at a slightly lower level. Enlarged to show the leaf bases. × 3

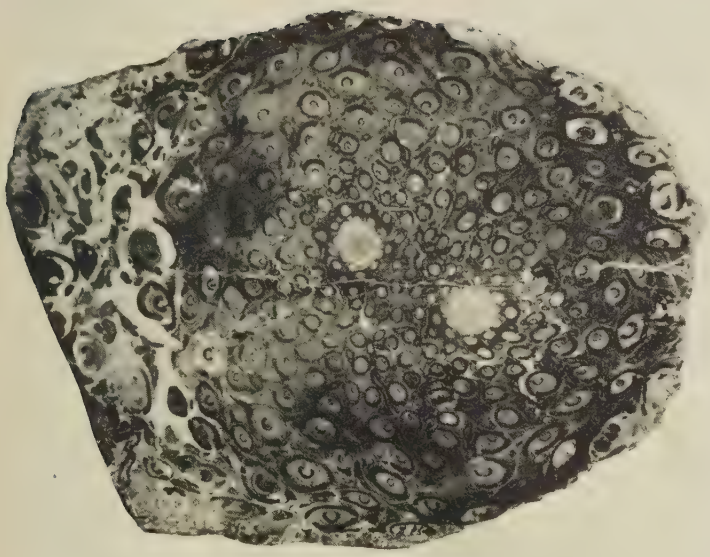


FIG. 1

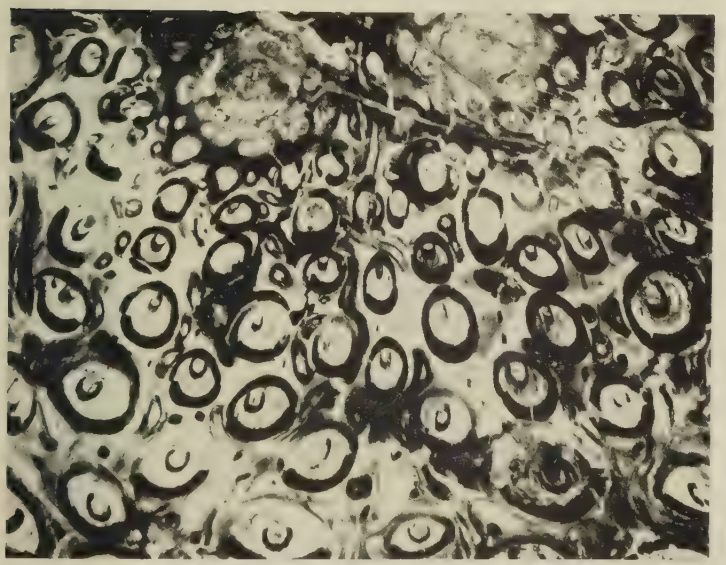


FIG. 2

EXPLANATION OF PLATE II

FIG. 1. *Eorhachis lomarioides*, gen. et sp. nov. Holotype. × 3

FIG. 2. *E. lomarioides*, gen. et sp. nov. Portion of holotype specimen illustrated in Figure 1, showing peripheral bundles and three inversely oriented bundles in the interior. The air spaces in the ground tissue are visible. × 20

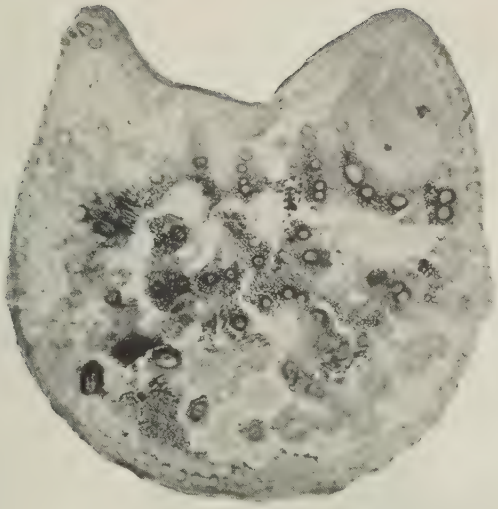


FIG. 1

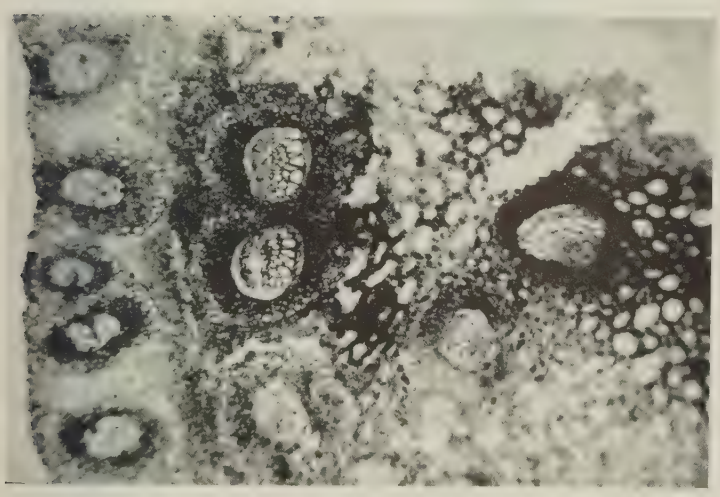
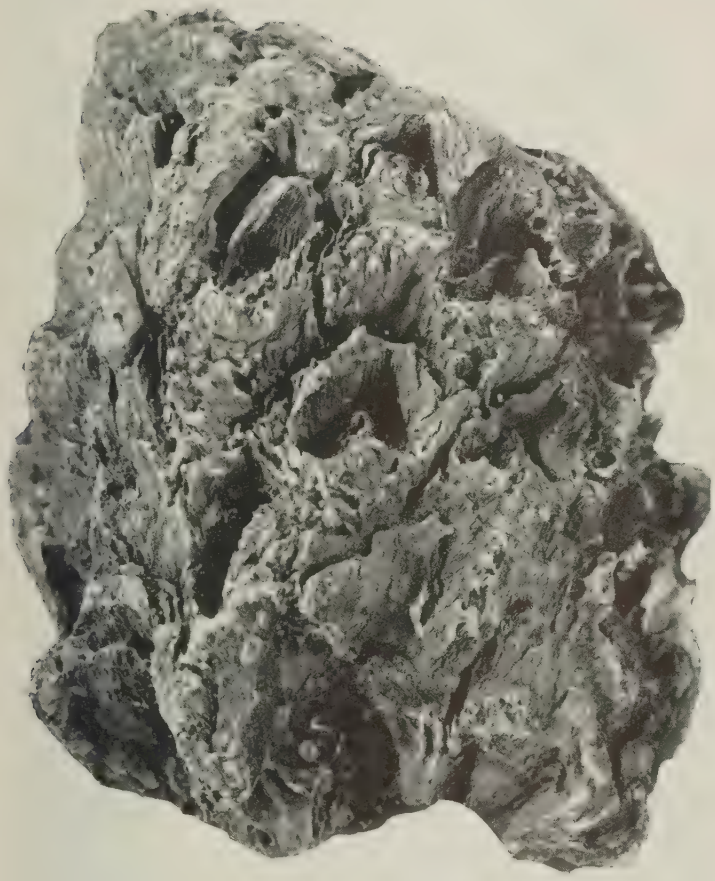


FIG. 2

EXPLANATION OF PLATE III

Cyathodendron texanum, gen. et sp. nov. Portion of short stem showing external features. × 1



EXPLANATION OF PLATE IV

FIG. 1. *Cyathodendron texanum*, gen. et sp. nov. Transverse section of holotype. × 1

FIG. 2. *C. texanum*, gen. et sp. nov. Portion of a transverse section, showing the numerous bundles of the medullary region. × 6

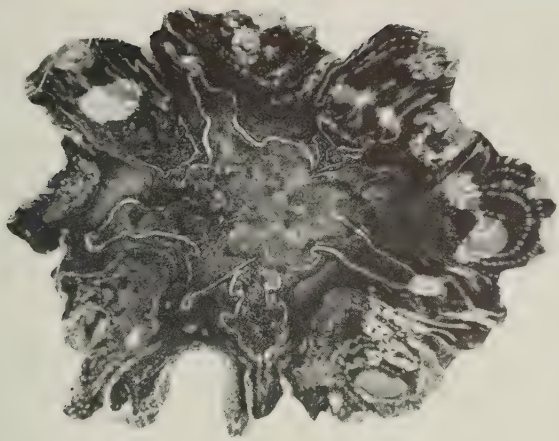


FIG. 1

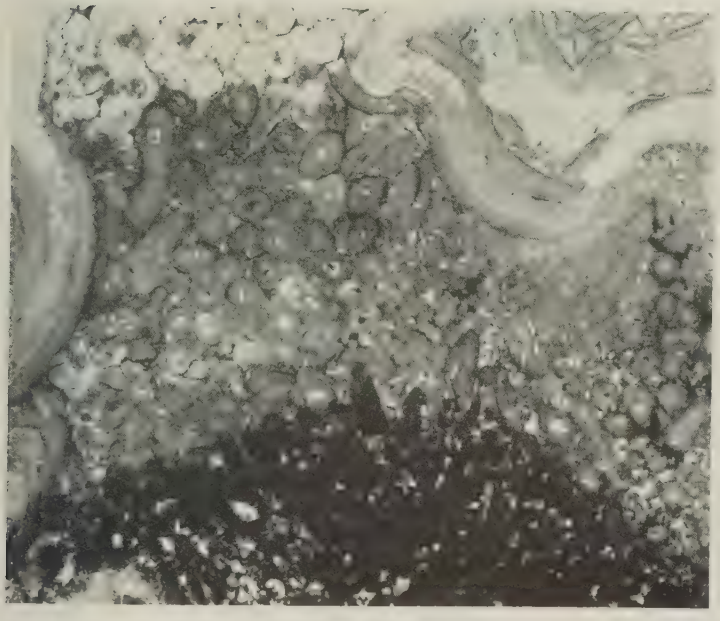


FIG. 2

EXPLANATION OF PLATE V

FIG. 1. *Cyathodendron texanum*, gen. et sp. nov. Transverse section, showing the outward prolongation of the solenostele to form the troughlike trace strand, and the numerous medullary bundles passing into the petiole. Paratype. × 3

FIG. 2. Section at slightly higher level than that shown in Figure 1. The lower extremity of the compensation tongue appears in the space corresponding to the leaf gap. Holotype. × 2½

FIG. 3. Section slightly above the level shown in Figure 2. The compensation tongue has closed the leaf gap, and the trace has become detached from the solenostele. × 2½

FIG. 4. Section just below point of separation of the petiole from the stem, showing the closed solenostele and the leaf trace of separate bundles. × 2½

FIG. 1

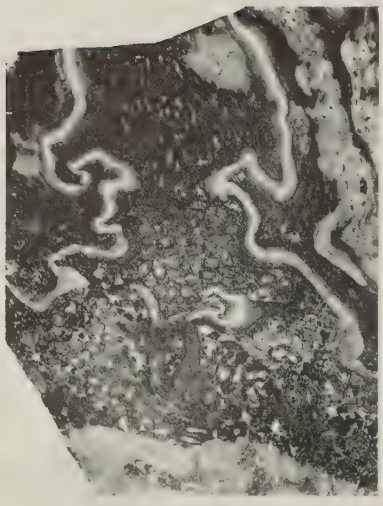


FIG. 2

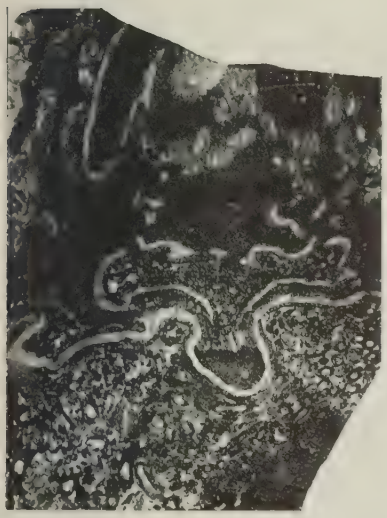


FIG. 3

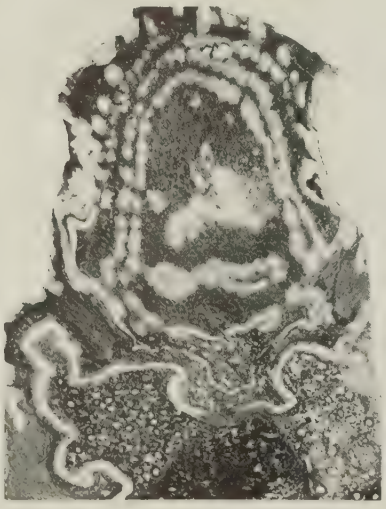


FIG. 4

EXPLANATION OF PLATE VI

FIG. 1. *Cyathodendron texanum*, gen. et sp. nov. Medullary strand in the central part of the stem. Holotype. × 120

FIG. 2. Portion of the solenostele of the holotype, showing the xylem, the narrow strip of disintegrated phloem, and the sclerenchymatous sheath. × 125

FIG. 3. Portion of the ramentum of multicellular hairs covering the surface between the leaf bases. Holotype. × 80

FIG. 4. Portion of the holotype, showing the tracheids in transverse section. × 475

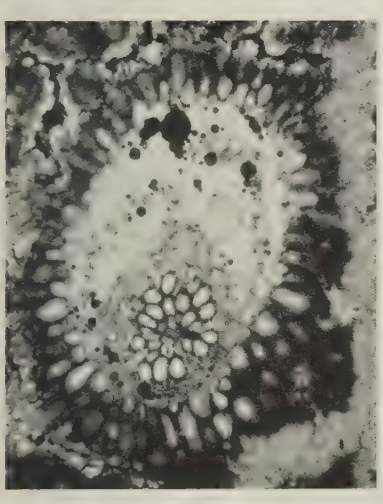


FIG. 1

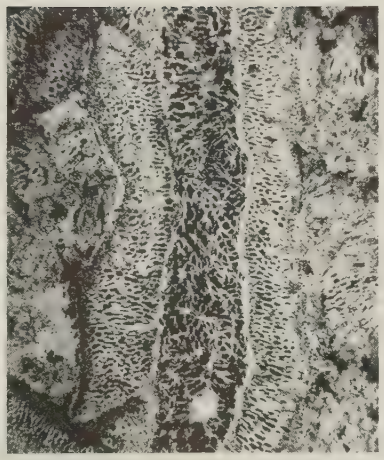


FIG. 2

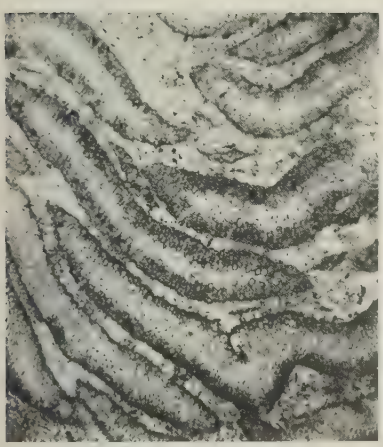


FIG. 3

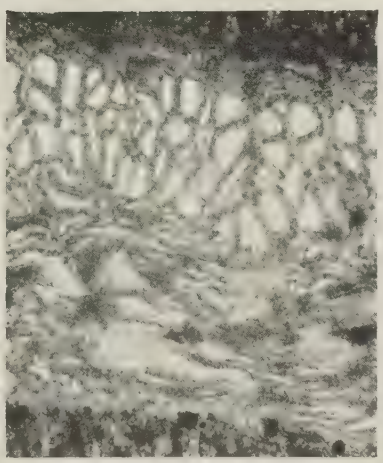


FIG. 4

EXPLANATION OF PLATE VII

FIG. 1. *Dawsonia* [illegible] n. sp. [illegible] from the placer deposits at Greenhorn, Oregon. Paratype. × 1

FIG. 2. Vascular cylinder of a single stem of the specimen shown in [illegible] × 7

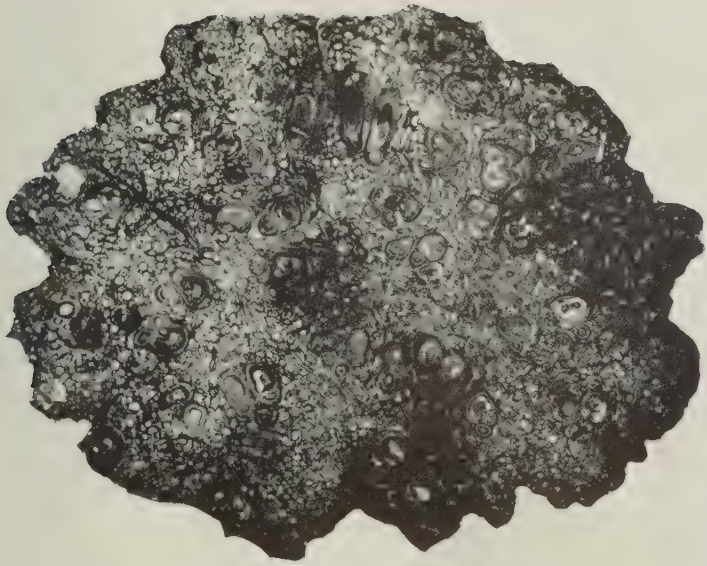


FIG. 1

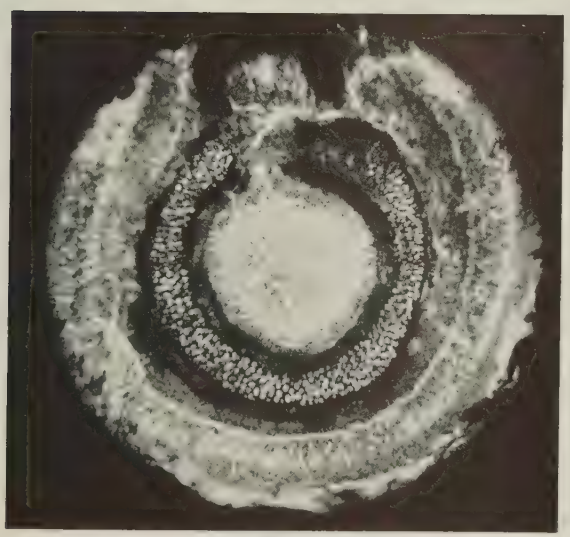


FIG. 2

EXPLANATION OF PLATE VIII

FIG. 1. *Tempskya Wesselii*, sp. nov. Transverse section of two stems embedded within the root mass. From Great Falls, Montana. Holotype. × 9

FIG. 2. Root mass of specimen shown in Figure 1. × 24

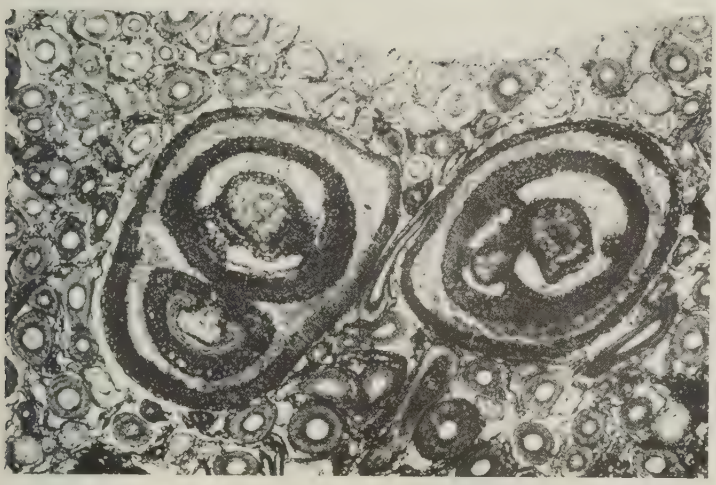


FIG. 1

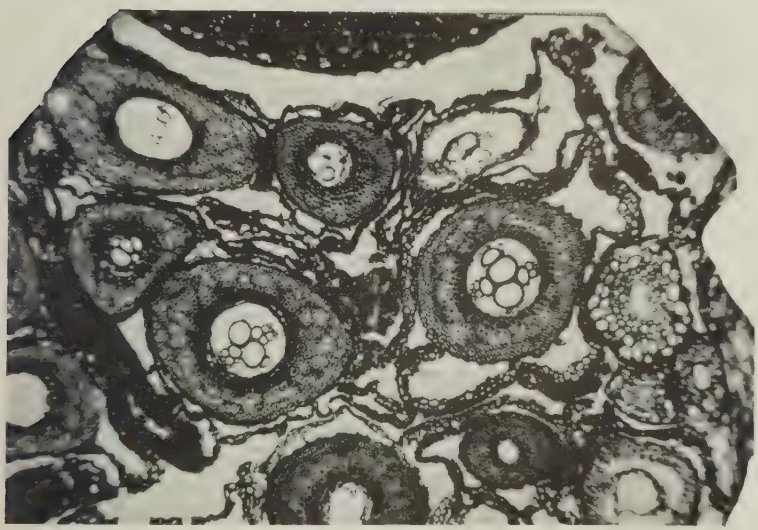


FIG. 2

EXPLANATION OF PLATE IX

FIG. 1. *Tempskya Wesselii*, sp. nov. Transverse section of stem, showing the three layers of the cortex. Most of the xylem tissue has disappeared. Holotype. × 63

FIG. 2. Portion of the inner cortex of the specimen shown in Figure 1, enlarged to make clear the two bands of stone cells. × 110

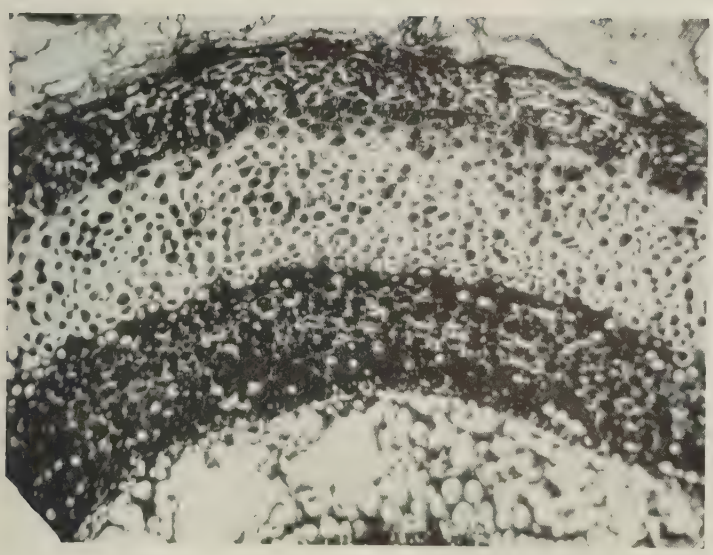


FIG. 1

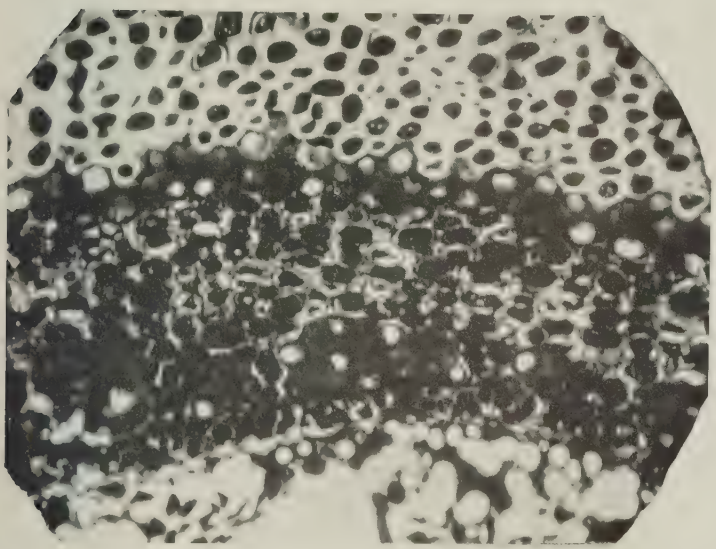


FIG. 2

EXPLANATION OF PLATE X

FIG. 1. *Tempskya wyomingensis*, sp. nov. Transverse section of the stem, showing two departing traces and a detached petiole (phyllopodium). Holotype. × 6

FIG. 2. Two stems from the holotype, showing departing traces and adventitious roots. × 6

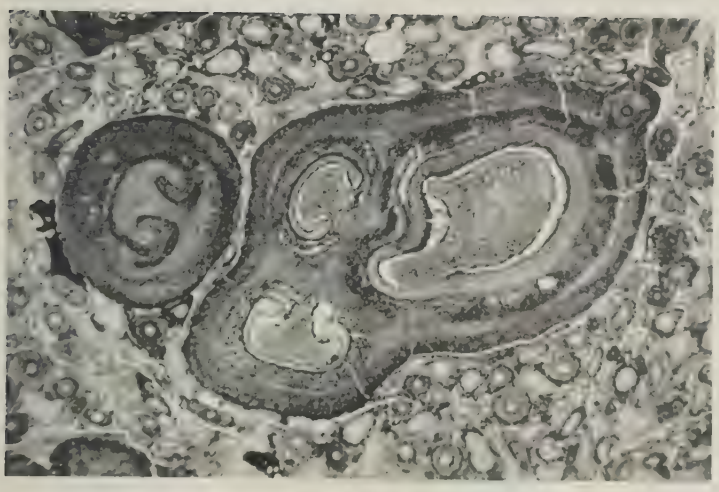


FIG. 1

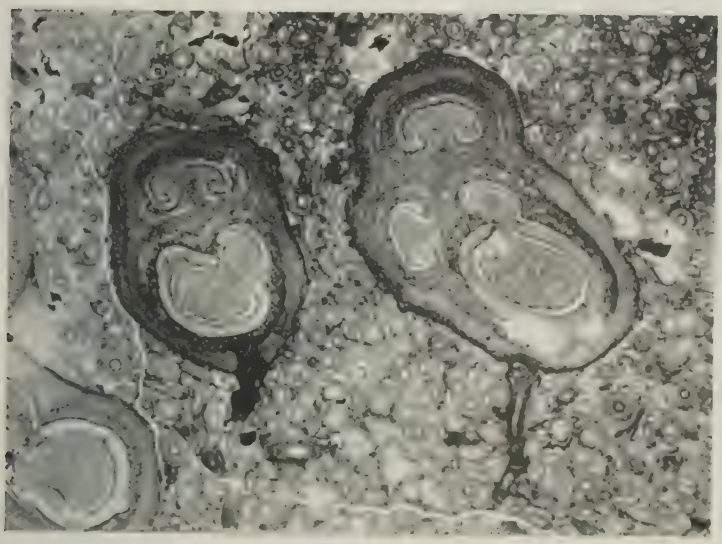


FIG. 2

EXPLANATION OF PLATE XI

FIG. 1. *Tempskya wyomingensis*, sp. nov. Portion of false stem, showing several stems and petioles embedded within the root mass. Holotype. $\times 2\frac{1}{3}$

FIG. 2. *T. grandis* Read et Brown. Section showing two or more roots surrounded by a common layer of parenchyma. Root hairs are visible in places. Material from Wheatland County, Montana. No. 23400 Univ. of Mich. Coll. $\times 25$

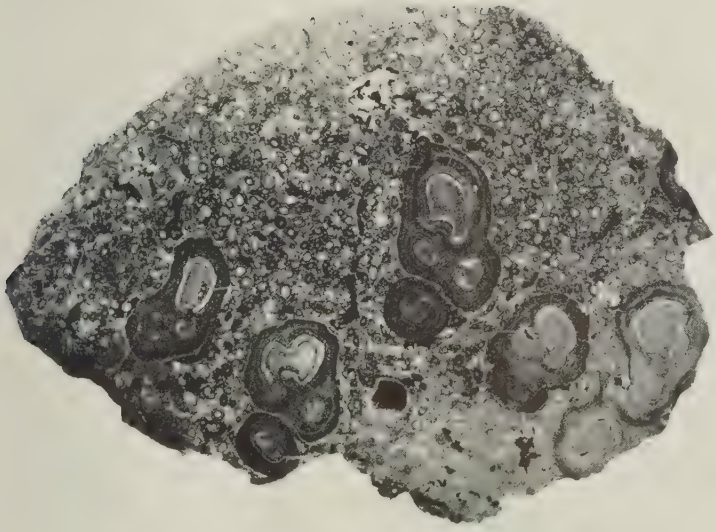


FIG. 1

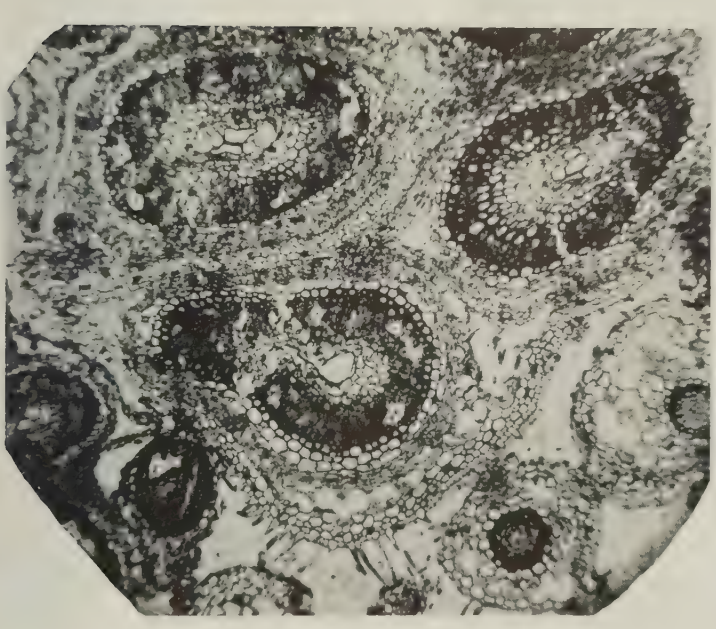


FIG. 2

PACIFIC SPECIES OF GALAXAURA
I. ASEXUAL TYPES *

RUTH CHEN-YING CHOU

THE genus Galaxaura, comprising calcified members of the Chaetangiaceae (Rhodophyceae), is morphologically of great interest to the botanist, although economically unimportant. The first specimens that were scientifically described were treated as polyps by Ellis and Solander (1786), under the name Corallina — a genus which, when first established by Linnaeus, contained all polyp-like animals and plants, but which is now entirely limited to a restricted genus Corallina, a group of calcareous red algae. After Ellis and Solander all naturalists working with the polyps adopted their classification, with the exception of Gmelin (1788) and Esper (1830), who put some of the species with Tubularia, which, in modern literature, is an animal genus of Hydrozoa (Coelenterata). In 1812 Lamouroux properly evaluated these so-called "polyps" as at least a distinct genus in a newly established family Corallineae, which included several genera of coralline algae. Nevertheless, like his contemporaries, he was not ready to give up the idea that these plants were animals, and so he regarded his family Corallineae as made up of "polypiers phytoides," or plantlike polyps.

For over three years I have given much time to a taxonomic study of the genus, hoping to bring together all these marine plants and their descriptions for a revision. Unfortunately, the spread of the war throughout the areas inhabited by them has made them unavailable and rendered it impossible to obtain additional working material or to borrow type specimens. Consequently, the intended scope of research has been narrowed down to include only the Pacific species of Galaxaura.

This investigation covers the Galaxaura flora of both the west and the east sides of the Pacific basin. A collection from the Philip-

* Papers from the Department of Botany and the Botanical Garden of the University of Michigan, No. 740.

pine Islands made by Professor H. H. Bartlett in 1935, together with collections from Java and Sumatra by Kostermans in 1938, typifies the Galaxaura flora of the western part of the tropical Pacific Ocean. Professor W. R. Taylor's specimens, secured by him on the Hancock Expedition in the years 1934 and 1939, are representative of the flora found along the eastern part of the tropical Pacific Ocean. In the materials from these two sources are eleven asexual species, including three new ones, and ten sexual species, with one new. To both gentlemen I am much indebted for furnishing materials for this investigation and for reviewing the manuscript. Special thanks are due to Professor Taylor for his critical guidance throughout the course of this study and to Professor Bartlett for other assistance. I am deeply grateful to the Levi Barbour Oriental Girls' Scholarship Fund of the University of Michigan, under which part of the research was carried on.

The plants of the genus Galaxaura are widely distributed in tropical and subtropical waters. They occur in the latitudes between 40° N. and 40° S. — northward as far as Japan and southward to Australia and the Cape of Good Hope, Africa.

The taxonomy of these plants is very incompletely known because the species within each division lack clear, definite differentiating features. Some plants may look identical in gross habit, but be entirely different in their cellular structure, as are members of the sections Arboreae and Vepreculae. Others may vary externally, but be similar in their structural organization, for example, *G. barbata* and the flattened species of the Arboreae or plants in the Oblongatae section.

The taxonomy is further complicated by the sexual dimorphism of the plants, first adequately demonstrated by M. A. Howe (1916, 1918). It is quite probable that the species are only half as numerous as the specific names hitherto proposed, but because of dimorphism each plant has received two names — one for the asexual and one for the sexual generation of the life cycle. The exact correspondence between the presumed alternate generations cannot be settled for individual species without comprehensive studies in the field with this point in view, or else without cultural studies. It cannot be settled by a comparison of herbarium specimens. In view of this fact the plants have had to be arbitrarily separated into sexual and asexual groups of nominal species. Each recognizable assemblage

of morphologically distinct plants is treated as an independent individual while we are awaiting recognition of the other phase in the life cycle. Whenever pairing is plausible it is mentioned in the discussions; Howe's hypothesis of sexual dimorphism is therefore tested so far as possible with herbarium materials.

In the Galaxaurae, because of the uncertainties of their life history, no attempt is here made toward the interpretation of the synonymy. All the species hitherto established, some doubtful as they may be, are maintained, and the identification of the plants on hand depends entirely on how closely they fit the type descriptions.

This paper (Part I of the whole study) deals with the asexual types only; the sexual plants will be treated in Part II, to appear in a later publication, which will complete the record of the Pacific species of Galaxaura.

NOMENCLATURE OF THE SECTIONS

It is to be regretted that Kjellman did not pay very much attention to the choice of sectional names when he wrote his monograph on Galaxaura. Of the sectional names used by him some are in correct form, as recommended by the International Rules, i.e. adjectives (preferably taken from representative or best-known species) in the plural, but other coördinate names are such as would be proper for subgenera, namely, substantives in the singular. Not only is it objectionable to have these two types of names used for coördinate generic subdivisions of the same category, but it is not appropriate to intersperse with them, as Kjellman did, some Latin adjectives used in the singular as substantives and others in the plural, apparently in the neuter gender instead of the feminine, as they would have to be in the genus Galaxaura.

I therefore propose certain modifications of Kjellman's sectional names, with the understanding that such names as Rhodura and Microthoë would be available for consideration as retained subgeneric names in a natural classification based upon characteristics of both the sexual and the nonsexual phases of the species. The emended list of sections is as follows:

Subverticillatae for Rhodura
Squalidae for Microthoë
Oblongatae for Eugalaxaura
Arboreae for Brachycladia

Vepreculae (no change)
Angustifrondes for Laevifrons
Robustae for Dichotomaria Cameratae
Umbellatae for Dichotomaria Spissae

It is to be noted that the type or standard species of Galaxaura is *G. umbellata*. This species must therefore be included in any subgenus named Eugalaxaura, if the rules and ordinary usage are to be followed. Kjellman's classification does not include *G. umbellata* in his section Eugalaxaura, and so it is necessary to suppress his subgenus by this name; reconstituting it with the type included would only cause confusion.

KEY TO THE SPECIES OF GALAXAURA

ASEXUAL TYPES

Plants asexual or tetrasporic; branches terete throughout or flattened above, villous or glabrous; short assimilatory filament either of the type of the Subver-

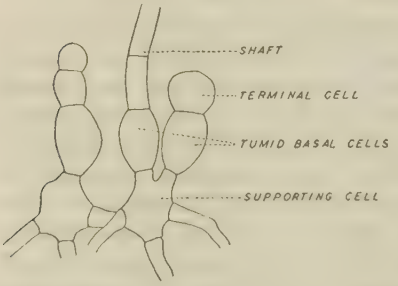


Fig. 1. Type of the Subverticillatae

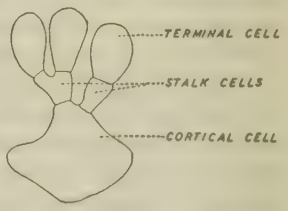


Fig. 2. Type of the Arboreae

ticillatae (Fig. 1), composed of a tumid basal cell and one or two terminal cells, or of the type of the Arboreae (Fig. 2), composed of stalk and terminal cells.

1. Plants with branches terete throughout 2
1. Plants with branches flattened above, although terete below (Section Arboreae) 8

2. Branches glabrous, robust, 2–4 mm. thick; segments turgid, articulate, or subarticulate ..... (Section Robustae) *G. robusta*
2. Branches villous or hirsute, bearing extended assimilatory filaments; slender, not over 2 mm. in diameter..... (Section Subverticillatae) 3

3. Assimilatory portion homogeneously filamentous, composed only of extended assimilatory filaments; supporting cells undifferentiated; tumid basal cells absent ..... *G. filamentosa*
3. Assimilatory portion heterogeneous, composed of both extended and short assimilatory filaments; supporting and tumid basal cells present 4

4. Short assimilatory filaments of the type of the Arboreae (Fig. 2); extended filaments verticillate at base of each proliferation .... *G. barbata*
4. Short assimilatory filaments of the type of the Subverticillatae (Fig. 1); extended assimilatory filaments all over the thallus 5

5. Terminal cells of short assimilatory filaments wider than basal cells; both extended and short assimilatory filaments fasciculate *G. fasciculata*
5. Terminal cells of short assimilatory filaments subequal or narrower than basal cells; short and extended assimilatory filaments not fasciculate 6

6. Short assimilatory filaments predominantly two-celled, rarely three-celled ..... *G. ramulosa*
6. Short assimilatory filaments commonly three-celled, some two-celled ... 7

7. Short and extended assimilatory filaments subverticillate; terminal cells of short assimilators smaller, narrower than basal cells .. *G. subverticillata*
7. Short assimilatory filaments few, evenly scattered among the extended ones; terminal cells variable, subequal, narrower, or wider than basal cells ..... *G. subfruticulosa*

8. Cortical tissue 20–60 μ thick, 1–2-stromatic 9
8. Cortical tissue 60–80 μ thick, 2–3-stromatic ..... *G. spathulata*

9. Thallus 2.0–3.5 mm. wide, angles wide; terminal cells of the short assimilators often apiculate ..... *G. apiculata*
9. Thallus 1–2 mm. wide, angles round or acute; terminal cells of the short assimilators round or acute 10

10. Branches continuous, proliferations few ..... *G. arborea*
10. Branches proliferous, constricted, or subarticulate; upper parts sometimes continuous; proliferations at the base surrounded by tufts of extended assimilatory filaments ..... *G. stupicaulis*

Galaxaura filamentosa, sp. nov. — Pl. I, Figs. 1–6; Pl. VI, Fig. 1

"*Galaxaura rudis* Kjellm." as misidentified by Tanaka, 1936, p. 145, figs. 1–2; pl. 34, fig. 1; Tseng, 1941, pp. 85–86, fig. 1.

Planta 3.5–5 cm. alta ad substratum disco adfixa, frondibus teretibus cum filamentis assimilatoriis dense vestitis; dichotome ramosis vel interpositione rami adventivi ut videtur trichotome ramosis; internodiis 2–10 mm. longis, 0.5–1.5 mm. crassis (filamentis liberis haud inclusis); thallo ex filamentis in parte media intertextis, in parte exteriore parallelis constato sed structura homogeneo sine cortice; filamentis axialibus 16–24 μ diam., apice in filamenta assimilatoria chromatophoria transeuntibus per cellulas sustinentes non aut raro maleque differentiatas; absque cellulis basalibus tumidis; parte filamentorum assimilatoriorum libera 1–4.5 mm. longa, simplici vel irregulariter ramosa, ex cellulis cylindricis constante inferioribus 16–18 μ diam., et superioribus 20–22 μ diam., sesquiplo vel triplo

longioribus quam crassioribus. Specimen typicum legit W. R. Taylor, no. 39–46, in republica Mexicana, in loco dicto Sulphur Bay, Clarion I., Revilla Gigedo Ins., Mar., 1939; in herb. "Hancock Foundation," Univ. South. Calif.; duplum in herb. Univ. Mich.

Plants bushy, 3.5–5.0 cm. high, attached by a small discoid holdfast; fronds terete, throughout densely covered by extended assimilatory filaments; branching more or less dichotomous, sometimes appearing trichotomous by development of adventitious branches; internodes 2–10 mm. long, 0.5–1.5 mm. thick (excluding extended filaments); thallus structurally filamentous, homogeneous, without differentiation of medullary and cortical layers; axial filaments 16–24 μ in diameter, their free ends extended into assimilatory chromatophore-bearing filaments with poorly developed or undifferentiated supporting cells; tumid basal cells totally absent; shaft of the assimilatory filaments 1.0–4.5 mm. long, simple or branched, composed of cylindrical cells, basal part 16–18 μ in diameter, the upper 20–22 μ in diameter, the length of individual cell 1.5–3 times as long as the diameter.

This new species is anatomically simpler than all the Subverticillatae hitherto described. Phylogenetically it may be closely related to Kjellman's *G. rudis* from the vicinity of Tonga, under which name the plants have undoubtedly been reported. The present investigation, however, shows that the assimilatory filaments of the Mexican and the Ecuadorian plants have only poorly developed or undifferentiated supporting cells, and the tumid basal cells, which are prominent in all other species, are entirely absent; thus the thallus is homogeneously filamentous throughout, with no differentiation between medullary and cortical tissues. Because of this I have considered these plants from the northern Pacific waters distinct from *G. rudis* of the southern Pacific; the latter species is clearly illustrated and described by Kjellman as having well-developed supporting and tumid basal cells.

Tanaka (1936) and Tseng (1941) reported the collecting of *G. rudis* in Formosa and on Hainan Island, respectively. Both authors have stated that their plants differ from Kjellman's *G. rudis* of the southern Pacific in having undifferentiated tumid and supporting cells. Therefore I am strongly inclined to think that the Chinese and the Formosan plants are identical with the Mexican and the Ecuadorian plants, or, at least, are distinct from *G. rudis*.

Specimens studied. — Mexico: Sulphur Bay, Clarion Island, Revilla Gigedo Isands, *Taylor 39–46* (type), March 17, 1939; Costa Rica: Golfo Dulce, *Taylor 39–93*, March 26, 1939; Port Culebra, *Taylor 34–533*, Feb. 24, 1934; Ecuador: Isabela Island, Archipelago de Colon, *Taylor 34–110*, Jan. 12, 1934.

Further distribution. — Formosa, Hainan Island.

Galaxaura subfruticulosa, sp. nov. — Pl. II, Fig. 6; Pl. VIII, Fig. 2

Kjellman, 1900, pp. 51–53, pl. 4, figs. 4–16, pl. 20, fig. 19; (probably) Tanaka, 1936, p. 148, figs. 7–8, pl. 35, fig. 2; Tseng, 1941, pp. 87–92, fig. 3.

Plantae 5–6 cm. altae, ad substratum disco crasso adfixae; ramis villosis, saepe irregulariter dichotomis; internodiis 3–12 mm. longitudine; filamentis assimilatoriis aequaliter densis in omnibus thalli partibus; brevibus in partibus vetustioribus, longioribus interdum subverticillatis in partibus apicalibus et in basi proliferationum, longitudine plerumque minus quam 1 mm.; proliferationibus solitariis ad basim depressionum cupuliformium insertis; filamentis medullariis 6–18 μ, raro 24 μ, diam.; filamentis peripheralibus ex cellulis sustinentibus plerumque male differentiatis etiamque cellulis assimilatorum basalibus tumidis ovoideis vel pyriformibus 45–65 μ longis, 28–40 μ crassis constantibus; brevibus filamentis assimilatoriis paucis, inter alia extensa dispersis, 2-cellulis vel 3-cellulis; cellulis terminalibus subglobosis, 20–34 μ diam., interdum paululo angustioribus quam cellulis subterminalibus atque basalibus; parte filamenti assimilatorii libera simplici vel raro ramosa, basi 14–16 μ diam., superne 16–18 μ diam.; cellulis duplo vel triplo longioribus quam crassioribus. Specimen typicum legit W. R. Taylor, no. 34–53, in republica Mexicana, in loco dicto Sulphur Bay, Clarion I., Revilla Gigedo Ins., Jan., 1934; in herb. "Hancock Foundation," Univ. South. Calif.; duplum in herb. Univ. Mich.

Plants 5–6 cm. high; attached to substratum by a broad discoid holdfast; branches villous throughout, often less regularly dichotomous; internodes 3–12 mm. long; the extended assimilatory filaments evenly distributed over the entire surface of the thallus, short on the older parts of the branches, longer and sometimes appearing subverticillate at the apex of the branches and at the base of proliferations, rarely attaining a length of 1 mm.; proliferations singly

emitted, base cupuliform; medullary filaments 6–18 μ, rarely to 24 μ in diameter, peripheral tissue consisting of supporting and tumid basal cells of the assimilators, the former commonly not well developed; tumid basal cells oval or pyriform, 45–65 μ long, 28–40 μ in diameter; short assimilatory filaments few, scattered among the extended ones, either two- or three-celled, terminal cells subglobose, 20–34 μ in diameter, equaling or slightly narrower than the subterminal and basal cells; shaft of the extended assimilatory filaments simple, occasionally branched, the basal part 14–16 μ in diameter, 16–18 μ above, cells 2–3 times as long as diameter.

These plants from Mexico have offered a real problem in the determination of the species. They share some characteristics with several members of the Subverticillatae, exhibiting no particularly distinctive traits, and still do not coincide satisfactorily with any known species.

In habit the thallus is villous, with the extended assimilatory filaments evenly distributed as in *G. ramulosa*, although the villi of the Mexican plants are not so long as those of *G. ramulosa*. The short assimilatory filaments, which are commonly few, are scantily scattered among the numerous extended assimilatory filaments. They are either two- or three-celled; when two-celled, they resemble the short assimilatory filaments of *G. ramulosa;* when three-celled, those of *G. subverticillata*, except that the terminal cells are subequal or slightly narrower than the subterminal and the basal cells, but not always so narrow as those of *G. subverticillata*. Furthermore, it is not uncommon to find the tumid basal cells bearing lateral branches for terminal cells, and rhizoidal or stoloniferous filaments connecting with adjacent cells or the medullary filaments — a characteristic distinctly exemplified in *G. fasciculata*. All these "mimetic" features complicate the sure determination of the species.

G. subfruticulosa may also be more or less closely related to Kützing's *G. tomentosa* from the east coast of Mexico, a species to which I was tempted to refer the present plants from the west coast of Mexico. Kützing's illustration in *Tabulae phycologicae*, Vol. VIII, p. 38, fig. 2, quite evidently shows that *G. tomentosa* does not have any short assimilatory filaments. All the assimilators are long and are composed of moniliform cells, with those near the basal part larger and the filament tapering gradually upward. It is, therefore, quite different from *G. subfruticulosa*.

Again, I was inclined to consider these plants identical with a Japanese species which has been called "*G. fruticulosa* Kjellm." because they agree with that species more closely than with other species of the Subverticillatae. As the studies proceeded, however, I discovered that *G. fruticulosa* was not first established by Kjellman at all, but, rather, is a name given by Lamouroux (1816) to Ellis and Solander's *Corallina fruticulosa* from the Bahama Islands. Curiously enough, whether through an oversight or a typographical error, Kjellman, in describing a Japanese plant, also called it *G. fruticulosa*, adding his own name as the specific authority. In the monograph he disregarded Lamouroux's early *G. fruticulosa* of the Bahama Islands, although, of course, he was familiar with and cited both Ellis and Solander's and Lamouroux's works. Furthermore, Lamouroux's *G. fruticulosa* was originally correctly cited by De Toni in *Sylloge algarum* (Vol. IV, Sectio I, p. 115. 1897). De Toni's work was also cited by Kjellman, so that it is almost unexplainable how he could have neglected the priority of the Bahaman species. This mistake of entirely disregarding the presumably valid early *G. fruticulosa* Lamouroux of the Bahamas and maintaining the distinct Japanese plant under the homonym *G. fruticulosa* Kjellman was made originally by Svedelius (1911), and later in De Toni's *Sylloge algarum*, Sectio V, Additamenta, 1924. The error has been repeated in recent publications, by Tanaka in 1936 and by Tseng in 1941. Regardless of whether or not the Japanese plant under the name "*G. fruticulosa* Kjellm." is identical with the Bahaman plant, the correct citation for the name is *Galaxaura fruticulosa* (Ell. & Sol.) Lamouroux, and if the Japanese plant of Kjellman is different, it must have a new name.

The verification of the Bahaman and the Japanese species would necessitate inspection of both types, and the existence of Ellis and Solander's type of *Corallina fruticulosa* is doubtful. Under such circumstances it seems best to treat these plants from the Pacific waters separately from the West Indian species. In view of this the plants from Clarion Island off the west coast of Mexico are described under a new name. Kjellman's homonymous "*G. fruticulosa*" from Cape Nomo, Japan, as well as Tanaka's *G. fruticulosa* (Japanese plant) and Tseng's from Hongkong and Pratas Island may for the present (pending examination) be considered conspecific.

Specimens studied. — Mexico: Sulphur Bay, Clarion Island, Revilla Gigedo Islands, *Taylor 34–53* (type), Jan., 1934.

Further distribution. — Probably Pratas Island; Hongkong; several localities in Japan.

Galaxaura ramulosa Kjellman. — Pl. II, Figs. 3–5; Pl. VII, Fig. 1

Kjellman, 1900, pp. 50–51, pl. 3, figs. 24–26, pl. 4, figs. 1–3, pl. 20, fig. 18.

Plants 5–9 cm. high, attached by a discoid holdfast; branches more or less regularly dichotomous, villous; internodes 2–15 mm. long, 0.5–1.2 mm. in diameter; medullary filaments 6 20 μ in diameter, peripheral tissue composed of the supporting and tumid cells of the assimilators; supporting cells well developed, trigonal to polygonal, 30–35 μ high, 20–40 μ in diameter, each bearing one or two assimilatory filaments; tumid basal cells prominent, oval, obovate, or elliptical, 40–65 μ long, 20–40 μ in diameter; short assimilatory filaments two-celled, including basal and terminal cells; terminal cell subglobose, 20–32 μ in diameter, nearly as wide as its basal cell, rarely wider; shaft of extended assimilatory filaments 0.8–1.2 mm. long, 12–15 μ in diameter toward the base, and 18–20 μ above, cells 1–3 times as long as the diameter.

The species is characterized by the two-celled short assimilatory filaments whose terminal cells are nearly the same width as their basal cells.

So far as is known, *G. ramulosa* has not been reported since Kjellman's time; therefore this is the first record for Pacific waters and also the first for regions outside its type locality, Pernambuco, Brazil. I am sure, however, that the plant must have been collected and mistaken for other species of the Subverticillatae.

Type locality. — Pernambuco, Brazil.

Specimens studied. — Panama: Jicarita Island, west coast of Panama, *Taylor 34–243, 34–505*, Feb. 20, 1934.

Further distribution. — East coast of Brazil.

Galaxaura fasciculata Kjellman. — Pl. II, Fig. 2; Pl. VIII, Fig. 1

Kjellman, 1900, p. 53, pl. 5, figs. 1–9, pl. 20, fig. 14; Weber-van Bosse, 1921, pp. 211–212; Tanaka, 1936, pp. 147–148, figs. 5–6, pl. 34, fig. 3; Tseng, 1941, pp. 86–87, fig. 2.

Plants 5–9 cm. high; fronds terete, villous throughout; branches more or less dichotomous, sometimes quasi-umbellate from being proliferous or closely forking; internodes continuous or subarticulate, 2–20 mm. long, 0.8–1.5 mm. in diameter; extended assimilatory filaments fasciculate, 1–2 mm. long, fascicles evenly distributed; medullary filaments commonly 8–14 μ, rarely up to 24 μ in diameter, peripheral tissue composed of the supporting and tumid basal cells of the assimilators, the former commonly poorly developed or undifferentiated; tumid basal cells of the short assimilators subcylindrical to clavate, 25–50 μ long, 15–22 μ wide, often with lateral branches, therefore fasciculate; terminal cells subglobose or obpyriform, 28–46 μ in diameter; shaft of extended assimilatory filaments simple or rarely branched, 14–16 μ in diameter toward the base, 18–20 μ above.

Plants of this species can be recognized by the fasciculate arrangement of both the extended and the short assimilatory filaments, the characteristic particularly suggested in the specific name. The condition arises from the branching of the tumid basal cells and, so far as is known, is unique in the genus.

Type locality. — Celebes Islands.

Specimens studied. — Philippine Islands: Culion Island, Calamian Group, *Bartlett 15582, 15596*, July 27, 1935; Java: near Baai van Batavia, *Kostermans 429*, Oct. 11, 1938; west cape of Java, *Kostermans 689*, Oct. 18, 1938; Tonga: Mukualofa, *Brooks* in herb. Taylor, *20493*, Aug. 27, 1931.

Further distribution. — Japan, Formosa, Hainan, Malay Archipelago.

Galaxaura subverticillata Kjellman. — Pl. II, Fig. 1; Pl. VII, Fig. 2

Kjellman, 1900, p. 48, pl. 3, figs. 12–14, pl. 20, fig. 17; Børgesen. 1916, p. 92, fig. 97; Taylor, 1928, p. 141, pl. 21, fig. 17, pl. 31, fig. 6; Tanaka, 1936, pp. 146–147, figs. 3–4, pl. 34, fig. 2.

Plants 4–7 cm. high; branches dichotomous, subverticillately villous; internodes 3–10 mm. long, 1.0–1.5 mm. in diameter; extended assimilatory filaments 1 mm. long, forming narrow bands at regular or subregular intervals alternating with wider bands of short assimilatory filaments; medullary filaments 7–28 μ in diameter; the peripheral tissue composed of the supporting and basal

cells of the assimilators; supporting cells less well developed or undifferentiated, rarely trigonal or quadrate; tumid basal cells oval or elliptical, 40–76 μ tall, 25–46 μ wide; short assimilatory filaments commonly three-, rarely two-celled (including tumid basal cell), terminal and subterminal cells smaller than the basal cells; shaft of extended assimilatory filaments simple or sometimes branched above, 15 μ in diameter toward the base, the upper part 20 μ in diameter, cells 1–3 times as long as wide.

This species might easily be confused with *G. subfruticulosa*, but can be differentiated because its extended assimilatory filaments form narrow bands alternating with wider bands composed of short assimilatory filaments. The extended assimilatory filaments in *G. subfruticulosa* and other species of the Subverticillatae may sometimes appear to be subverticillate at the upper part of the branches, but these are usually not distinct and are wider than the short assimilatory bands. In other words, the development of extended assimilatory filaments in *G. subfruticulosa* exceeds that of the short assimilatory filaments, whereas in *G. subverticillata* the reverse is true. Furthermore, the short assimilatory filaments in *G. subverticillata* are commonly three-celled, with terminal and subterminal cells distinctly smaller than the tumid basal cell.

Type locality. — St. Croix, Virgin Islands.

Specimens studied. — Philippine Islands: Puerto Galera Bay, Mindoro Prov., *Bartlett 13787*, May 12–17, 1935; Lubang Island, Mindoro Prov., *Villaflores 7–8*, Aug. 24, 1935; *47*, Sept. 11–17, 1935.

Further distribution. — Bermuda, Florida, West Indies, Japan, East Indies.

Galaxaura robusta Kjellman. — Pl. III, Figs. 1–10; Pl. IX, Fig. 2

Kjellman, 1900, p. 85, pl. 18, figs. 19–22, pl. 20, fig. 42. Tanaka, 1936, pp. 170–171, pl. 45, figs. 38–39.

Plants up to 10 cm. high, with robust regularly dichotomous branches; basal attachment not seen; thallus cylindrical, becoming flattened when dried, thin, fragile after decalcification; segments plicate, constricted, or subarticulate at the nodes, 0.8–2.0 cm. long, 4 mm. in diameter; medullary filaments commonly 16 μ in diameter, ranging between 8 and 20 μ, the majority of them lying close to the periphery; cortical parenchyma monostromatic, cells large, sub-

globose or rectangular in section, 40–50 μ tall, 75–90 μ broad, each bearing 1–3 cylindrical stalk cells, 15–20 μ tall, 8–11 μ in diameter; terminal cells obconical, 16–18 μ tall, 30–40 μ broad at the outer wall, containing large stellate chromatophores with a pyrenoid at the center, cells closely arranged, angular in surface view, forming a layer of epidermis; tetrasporangia soriferous, clavate or obpyriform, 40–60 μ long, 25–30 μ in diameter at the upper end; spores tetrapartite, reniform or amygdaliform, 20–25 μ long, median diameter 10–12 μ.

The species is known to have branches coarser than those of any cylindrical asexual Galaxaurae hitherto described. Since this specimen from Tonga agrees in every noteworthy respect with the description and the illustrations given by Kjellman, it is easily referred to *G. robusta.*

Being an asexual member of the Robustae the species may pair, as suggested by Howe (1916), to complete a life cycle with one of the members of the Umbellatae. One may mention in this connection that there is a sexual specimen (*Bartlett 15022*) from Dalupiri Island, Philippines, which also has very coarse branches, although not quite so robust as those of the Tonga plant, which in many respects would fit the requirements for the sexual phase of *G. robusta.* The Philippine plant which I have called *G. umbellata* (Esp.) Lamouroux will be considered with the sexual plants in Part II.

Type locality. — Nossi Bé Island, Madagascar.

Specimens studied. — Tonga: Mukualofa, *Brooks*, in herb. Taylor, *20444*, Aug. 27, 1931.

Further distribution. — Nossi Bé Island, Malay Archipelago, Formosa, Japan.

Galaxaura barbata, sp. nov. — Pl. IV, Figs. 1–7; Pl. VI, Fig. 2

Plantae 5 cm. altae, ad substratum disco adfixae; ramis teretibus, siccitate ad apicem interdum compressis; plus minusve regulariter dichotomis, barbatis cum filamentis assimilatoriis divergentibus annulos angustos approximatos vel remotos formantibus, segmentis constrictis vel subarticulatis, 3–9 mm. longis, diam. 0.5–1.0 mm.; filamentis medullariis plerumque diam. 12–16 μ, sed inter 6 et 20 μ variantibus; cortice monostromatico, cellulis corticalibus grandibus,

ovoideis vel subglobosis, 32–50 μ diam., cellulas 1 vel 2 subcylindricas vel clavatas stipitiformes ferentibus, simplices vel furcatas; cellulis stipitiformibus aut cellulam singulam terminalem ferentibus aut si furcatis cellulas duas terminales subglobosas vel ovoideas vel clavatas, 28–44 μ altas, 20–28 μ diam., confertis, inter se compressis angulatisque, aspectu superficiali ut cohaerentibus; filamentis assimilatoriis divaricatis 1–2 mm. longis, 16–18 μ diam.; cellulis basalibus tumidis magnis, 90–120 μ longis, 28–40 μ diam., saepe granula amylacea includentibus. Specimen typicum legit W. R. Taylor, no. 34–364, ad Insulam Santae Mariae, Galapagos Ins., Jan. 27, 1934.

Plants 5 cm. high, attached to the substratum by a discoid holdfast; branches terete, apex sometimes compressed when dried, more or less regularly dichotomous, barbate with extended assimilatory filaments which form narrow rings with close or remote intervals; segments constricted or subarticulate, 3–9 mm. long, 0.5–1.0 mm. in diameter; the medullary filaments commonly 12–16 μ, ranging from 6 to 20 μ in diameter; cortical tissue monostromatic, cells large, ovate or subglobose, 32–50 μ in diameter, each bearing 1–2 clavate stalk cells, 12–24 μ long, 10–18 μ in diameter, simply bearing one terminal cell or slightly furcate at the distal end and bearing two; terminal cells subglobose, oval or clavate, 28–44 μ tall, 20–28 μ in diameter, much crowded, angular in surface view, appearing coherent with adjacent cells; the extended assimilatory filaments 1–2 mm. long, 16–18 μ in diameter, shaft cells cylindrical, 1–5 times as long as diameter; tumid basal cells very large, 90–120 μ long, 28–40 μ in diameter, often containing starch grains.

The species is a deep-water representative, dredged from a depth of 37 meters. It shows the characters of "Teretes" in habit but of Arboreae in structure. Phylogenetically it will probably find its nearest affinity in Kjellman's *G. lenta* from Ceylon Island, which likewise has terete branches throughout, whereas other species of the Arboreae all have flattened branches above. Furthermore, the strong development of the extended assimilatory filaments which occur in narrow rings at the lower parts of the branches and at the base of the proliferations distinguishes the present species from the glabrous or subglabrous *G. lenta*. The new species is also distinguished by having very large tumid basal cells, which are between 90 and 120 μ long and 28 and 40 μ in diameter. These measurements are, in fact, the greatest in all the plants I have examined.

These two species of terete Arboreae may bridge the gap between the Subverticillatae and the Arboreae. No definite conclusion can be drawn, however, until the life cycle of these algae becomes better known.

I was inclined to interpret the first specimen I saw as a juvenile stage of one of the Arboreae species, probably of *G. arborea*, the basal parts of whose branches are subterete and often villous, with rings of extended assimilatory filaments. Later, when a second specimen, collected by Schmitt from the Island of Santa Cruz, in December, 1934, came under my observation, the existence of another species became quite clear, and it is here recognized under a new name.

Specimens studied. — Ecuador: Santa Maria Island, Galápagos Islands, *Taylor 34–364* (type), Jan. 27, 1934; Island of Santa Cruz, *Schmitt 316–335*, Dec. 8, 1934.

Further distribution. — So far as is known, it is endemic in the Galápagos Islands.

Galaxaura stupicaulis Kjellman.[1] — Pl. V, Figs. 10–12; Pl. XI, Fig. 1

Kjellman, 1900, pp. 75–76, pl. 14, figs. 1–9, pl. 20, fig. 28.

Plants 6–7 cm. high, attached by a discoid holdfast; branches terete, villous below, flattened above, continuous, or proliferous with subarticulate constrictions, each encircled by a tuft of extended assimilatory filaments; segments 2–7 mm. long, 1–2 mm. wide, carnose-membranous, margins slightly thickened; the medullary filaments 7–15 μ in diameter; cortex parenchymatous, 1–2-stromatic, commonly 20–40 μ, rarely to 60 μ thick (excluding the stalk and the terminal cells), the inner cells large, subglobose or compressed, 20–44 μ tall, 25–50 μ broad, outer cells smaller, subglobose or pyriform, bearing 1–2 stalk cells; stalk cells cylindrical or cuneate-cylindrical, simple or once furcate, unicellular, rarely two-celled, 30–36 μ tall; terminal cells variable, subglobose, oval or clavate, 20–44 μ tall, 20–32 μ in diameter; extended assimilatory filaments 1 mm. long, with one or two tumid basal cells, size 58–76 μ long, 24–34 μ in diameter; shaft 15–16 μ in diameter, cells 2–5 times as long as the diameter.

[1] This name was published by Kjellman as *G. stupocaulon*, which, for the sake of correctness, should be modified to *G. stupicaulis*, since the adjective must agree with the generic name in gender.

In the group of Fruticulosae Kjellman named two species from Brazil, primarily on the basis of morphological differences: *G. frutescens*, characterized by not having decompound proliferations, the internodes 2–3 mm. wide, inconspicuously zonate, the margins not thickened; and *G. stupicaulis*, differentiated by having decompound proliferations, the internodes hardly over 2 mm. wide, distinctly transverse-zonate, and the margins thickened.

The distinctions regarded by Kjellman as specifically important could very easily be fluctuating variations only, and thus bear no taxonomic significance. In the discussion of *G. arborea* I mention that, because of the frequent occurrence of the verticillate-extended assimilatory filaments on these plants and on the Philippine plants, *Bartlett 15009A*, I am tempted to consider the present Costa Rican plants the same as the Philippine *G. arborea*, although the former are more proliferous.

The plants from Costa Rica were collected from intertidal rocks — a zone where plants are constantly subject to tidal and wave action and to periodic exposure; thus growth may not be normal and continuous. Such conditions may account for some of the specimens being extremely proliferous. However, since none of these differences have been tested by collectors in the field, I have, at least for the time being, decided to maintain Kjellman's *G. stupicaulis* and to refer the Philippine plants to *G. arborea*.

Among the collections there are some sexual plants accompanying the asexual ones, which are very probably the sexual phase of the same species. Because of my present treatment of the species these sexual plants are tentatively assigned to the species *G. veprecula*.

Type locality. — Bahia, Brazil.

Type specimen. — In Areschoug's herbarium, under the name *G. marginata*.

Specimens studied. — Costa Rica: Golfo Dulce, *Taylor 39–90A*, *39–91A*, March 26, 1939.

Further distribution. — Bahia, Brazil.

Galaxaura arborea Kjellman. — Pl. V, Figs. 1–5; Pl. X, Figs. 1–2

Kjellman, 1900, pp. 72–73, pl. 11, figs. 1–11, pl. 20, fig. 39. Tanaka, 1936, pp. 161–162, figs. 24–25, pl. 40; Tseng, 1941, pp. 94–95, fig. 6.

Plants densely bushy, deliquescent-arborescent, as much as 12 cm. high, attached by a broad, matlike or discoid holdfast; caudex and basal part of branches subterete, villous with rings of extended assimilatory filaments, sometimes subglabrous, above flattened, glabrous, carnose-membranous, continuous or proliferous, base of proliferations encircled by a tuft of extended assimilatory filaments; thallus 1–2 mm. broad, margins thickened, often with distinct transverse striations, at least toward the distal parts of branches; segments elongate-cuneate, 3–10 mm. long, 1.5–2.5 mm. wide; medullary filaments 8–16 μ in diameter, the cortical parenchyma tissue 20–60 μ thick, 1–2-stromatic, cells subglobose or compressed, 16–60 μ radially, 40–60 μ tangentially, each bearing 1–2 cuneate-cylindrical stalk cells, 18–25 μ tall, upper end simple or slightly furcate, 12–18 μ in diameter, lower 8–12 μ; terminal cells ovate or clavate, 22–36 μ tall, 18–25 μ in diameter, loosely arranged, appearing subglobose on the surface; extended assimilatory filaments 0.5–1.5 mm. long; tumid basal cells 1–2, size 50–70 μ long, 24–40 μ in diameter; shaft cells 18–20 μ in diameter, 2–4 times as long as broad.

The distinction between the Pacific *G. arborea* and the West Indian *G. frutescens* is so trivial that I often doubted the value of separation. In the Philippine collection plants under *Bartlett 15009A* agree very closely with Kjellman's description of *G. frutescens*, whereas his plants under *14608*, collected from the same locality but earlier in the season, showed vigorous growth and arborescent habit. At first I was tempted to call the former *G. frutescens* and the latter *G. arborea*, but since they all came from the same locality the minor external differences were treated as seasonal variations, and the plants were considered identical.

Type locality. — Australia.

Type specimen. — In J. C. Agardh's herbarium, under the name *Galaxaura marginata*.

Specimens studied. — Philippine Islands: Dalupiri Island, Babuyanes, *Bartlett 14608*, July 17; *15009A*, Oct. 5, 1935.

Further distribution. — Japan, Hongkong, Hainan Island, Australia, Hawaiian Islands.

Galaxaura apiculata Kjellman. — Pl. V, Figs. 13–19; Pl. IX, Fig. 1

Kjellman, 1900, pp. 74–75, pl. 12, figs. 13–26, p. 20, fig. 36; Tanaka, 1936, pp. 162–163, figs. 26–27, pl. 41, fig. 2.

Plants 8–9 cm. high (basal attachment not seen); branches flabellate, flattened, decompound-furcate, angles obtuse or round, often subtending 70°–90°; segments 5–12 mm. long, margins thickened; proliferations few, their bases encircled by tufts of extended assimilatory filaments; medullary filaments 8–12 μ, rarely 16–20 μ in diameter; cortical parenchyma monostromatic, cells large, subglobose or compressed, each bearing 1–2 cylindrical or cuneate-cylindrical stalk cells, 18–25 μ tall; terminal cells subglobose, oval or obpyriform, 40–50 μ tall, 40–44 μ in diameter, distal end wall apiculate; apiculi 2 μ tall, in older cells often attaining a sublateral position, thus not easily seen; extended assimilatory filaments 0.5–1.5 mm. long, 25–40 μ broad; shaft 12–15 μ in diameter, cells 3–4 times as long as the diameter.

The species is characterized by having mucronate terminal cells — a specific character established by Kjellman to distinguish the Japanese plant from *G. marginata* of the West Indies. This characteristic, however, has been questioned by Børgesen, who says that the numerous specimens he collected in the Danish West Indies agree in all essentials with Kjellman's description of the Pacific plants, except that the terminal cells of the West Indian plants end commonly, but not always, in a short apiculus. My observation of the West Indian *G. marginata* did not quite agree with Børgesen's, for in only two specimens, one from Bermuda, the other from the West Indies, did I detect a few sporadic mucronate cells, with apiculi not so tall as those of the Philippine and the Tonga plants.

The terminal cells of the Tonga plant have a slightly smaller diameter than those of the Philippine plants, but since both specimens show apiculate terminal cells they are treated as identical.

Since both specimens lack basal attachment, it is impossible to tell whether the plants are arboresent or frutescent. The Philippine plants were recorded as "cast up by waves," so that it is quite possible that they represent only parts of a plant broken off from the basal attachment, and might easily be caulescent, and thus agree in habit with Kjellman's *G. apiculata* from Japan.

Type locality. — Pacific Ocean near Japan.

Specimens studied. — PHILIPPINES: Puerto Galera Bay, Mindoro Island, *Bartlett 13782*, May 12–17, 1935; TONGA: Mukualofa, *Brooks* in herb. Taylor, *25494*, Aug. 27, 1931.

Further distribution. — Japan.

Galaxaura spathulata Kjellman. — Pl. V, Figs. 6–9; Pl. XI, Fig. 2

Kjellman, 1900, p. 74, pl. 12, figs. 5–12, pl. 20, fig. 35.

Plants to 18 cm. or more high, subcaulescent; caudex villous, warty, 3–4 cm. long, 4–6 mm. thick; branching dichotomous, angles acute, branches flattened, carnose- or subcoriaceous-membranous, continuous, rarely proliferous; segments 0.5–1.5 cm. long, upper end 1.5–3.0 mm., the lower 0.5–1.5 mm. in diameter, inconspicuously transversely striate, margins slightly thickened, tomentose when injured; apex of branches round, spathulate, or subfalcate; medullary filaments in the caudex 8–32 μ in diameter, peripheral filaments assimilatory or rhizoidal, with well-developed tumid basal cells forming cortical tissue; cortical parenchyma tissue 1–3-stromatic, 60–80 μ thick, the innermost cells largest, globose or compressed, 24–60 μ tall, 60–80 μ broad, the outer cells ovate or obpyriform, each bearing 1–2 cuneate-cylindical, simple or once-furcate stalk cells, 20–32 μ long; terminal cells variable, subglobose, oval, or obpyriform, 30–44 μ tall, 25–30 μ in diameter, much crowded, in surface view angular; extended assimilatory filaments 1.0–1.5 mm. long, with one or two tumid basal cells, 70–90 μ long, 30–40 μ in diameter; shaft 20 μ in diameter, cells 2–4 times as long as thick; marginal tomentum similar to young extended assimilatory filaments, cells shorter, 1–2 times as long as the diameter.

In habit these plants from Ecuador resemble in some respect each of the Pacific Arboreae described by Kjellman, and thus difficulty is encountered in identifying the species. Kjellman's specific recognition of these plants was primarily based on their general growth habit and the superficial forms of the branch tips — characters which may not be reliable for specific separation unless supported by structural features.

Perhaps I should call these Ecuadorian plants *G. arborea* instead of *G. spathulata* because they resemble both species in certain respects, and if future study should prove the species identical the former name would be valid because of priority. However, since the plants are tall like those of *G. spathulata* and since in habit they do not resemble *G. arborea* of the Philippine Islands, they are tentatively assigned to *G. spathulata*.

The collection includes a sexual plant which is likewise tall and

arborescent, resembling the asexual plant of *G. spathulata*. It may represent the sexual phase of *G. spathulata*, but is tentatively ascribed to the section Angustifrondes because of its smooth branches, whose epidermal cells are free from spinulose outgrowths.

Type locality. — Freemantle, Australia.

Type specimen. — In Areschoug's herbarium, under the name *Microthoë marginata* Decaisne.

Specimens studied. — Ecuador: Isabela Island, *Taylor 34–164*, Jan. 13, 1934; Santa Maria Island, Galápagos Islands, *Taylor 34–246*, Jan. 17–18, 1934.

Further distribution. — Australia.

SUPPLEMENTARY NOTE

The species *Galaxaura barbata* is closely related to *G. paschalis* Børgesen from Easter Island. (*See* F. Børgesen, "Marine Algae from Easter Island," *in* C. Skottsberg, *The Natural History of Juan Fernandez and Easter Island*, Vol. II, Part III, pp. 247–309, 50 figs. Uppsala, 1924; preprint dated 1920 on back cover.) Børgesen's species is likewise characterized by having cylindrical branches with well-developed whorls of hairs, but *G. barbata* differs from it in several respects. The terminal cells of the short assimilatory filaments of *G. barbata* are ovate or subglobose, and the cortical cells are well developed, forming a monostromatic layer of parenchymatous tissue, whereas the terminal cells in *G. paschalis* are two or three times as long as wide, and the cortical cells are either poorly developed or undifferentiated. The tumid basal cells of the extended assimilatory filaments in *G. barbata* are very large and prominent, and the corresponding cells as described by Børgesen are little differentiated. Unfortunately, Skottsberg's work escaped my notice until the present paper was in type, since Børgesen's species had not been referred to in the sources usually consulted. To judge from the description only (for I have not seen material from Easter Island), *G. paschalis* would key out to *G. barbata*, from which it should be easily distinguished by the contrasting characteristics here pointed out.

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EXPLANATION OF PLATE I

Galaxaura filamentosa

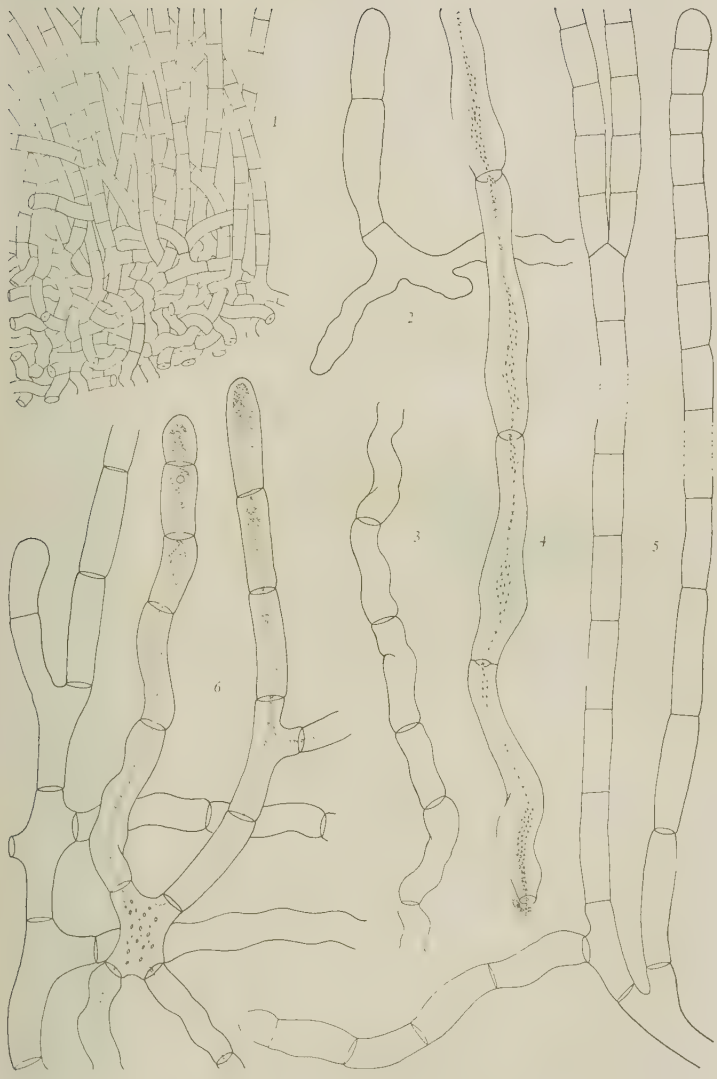
FIG. 1. Section of portion of thallus. × 140

FIG. 2. Young extended assimilatory filament. × 225

FIGS. 3–4. Medullary filaments containing starch grains. × 225

FIG. 5. Mature extended assimilatory filaments, showing branching. × 225

FIG. 6. Extended assimilatory filaments with undifferentiated or poorly developed supporting cells. × 225



Galaxaura filamentosa

EXPLANATION OF PLATE II

Galaxaura subverticillata

FIG. 1. Section of portion of thallus. × 195

G. fasciculata

FIG. 2. Section of portion of thallus, showing fasciculate short assimilatory filaments. × 195

G. ramulosa

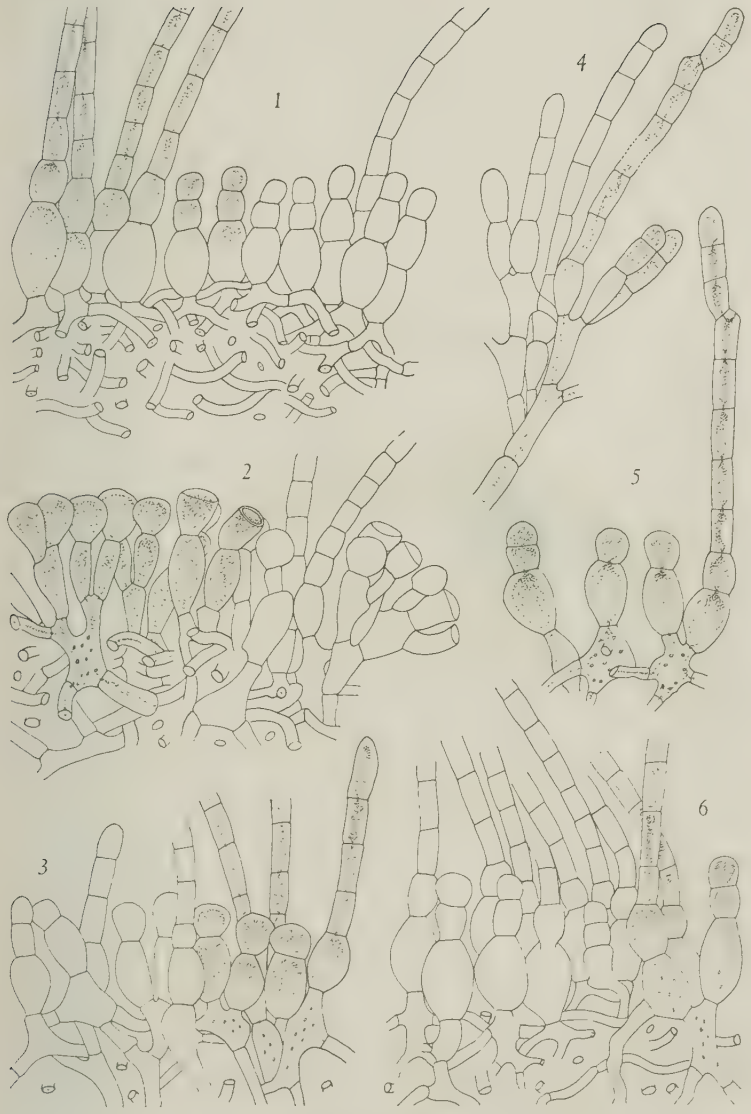
FIG. 3. Section of portion of thallus. × 195

FIG. 4. Various stages of extended assimilatory filaments. × 195

FIG. 5. Short and extended assimilatory filaments borne separately or by a common supporting cell. × 195

G. subfruticulosa

FIG. 6. Section of portion of thallus. × 195



Galaxaura species

EXPLANATION OF PLATE III

Galaxaura robusta

FIG. 1. Surface of thallus, showing terminal cells with large stellate chromatophores. × 340

FIG. 2. Section of thallus, showing assimilators and cortical cells. × 340

FIG. 3. Single cortical cell, with bifurcate stalk cell bearing two terminal cells. × 340

FIG. 4. Cortical cells, exterior view, showing stalk cells after terminal cells become detached. × 340

FIG. 5. Medullary filaments near periphery bearing cortical cells at the distal ends. × 340

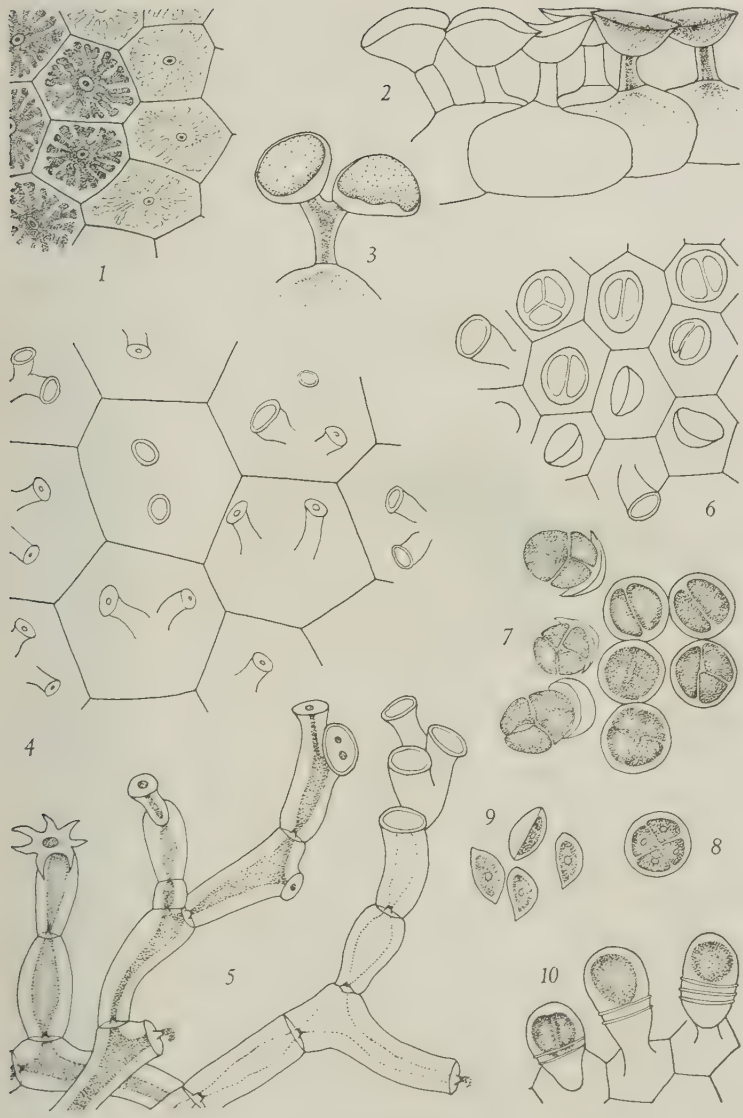
FIG. 6. Sorus, surface view. × 340

FIG. 7. Sporangia, showing cleavage of spore mother cells. × 340

FIG. 8. Mature sporangium with tetrads. × 340

FIG. 9. Mature spores. × 340

FIG. 10. Sporangia, lateral view, showing regeneration within old sporangia walls. × 340



Galaxaura robusta

EXPLANATION OF PLATE IV

Galaxaura barbata

FIG. 1. Habit of portion of plant, showing barbate extended assimilatory filaments. × 1.5

FIG. 2. Section of portion of thallus. × 340

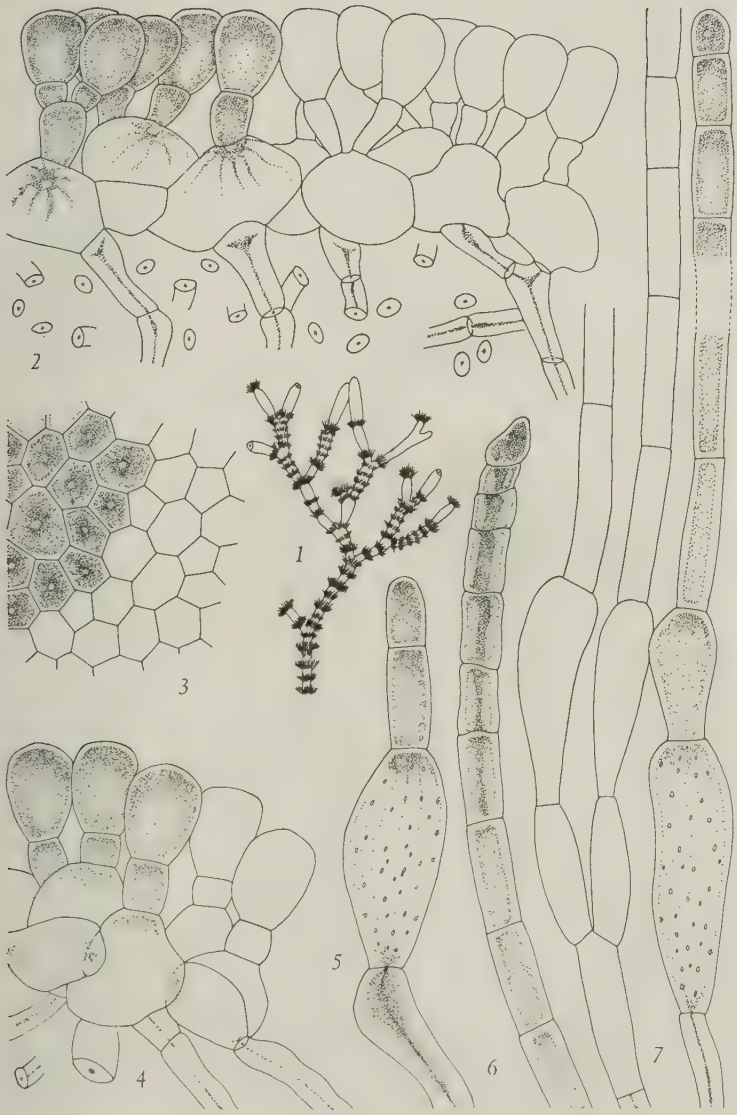
FIG. 3. Surface of thallus. × 340

FIG. 4. Section of portion of young thallus. × 340

FIG. 5. Young extended assimilatory filament. × 340

FIG. 6. Apical part of extended assimilatory filament. × 340

FIG. 7. Basal part of extended assimilatory filament, showing large tumid basal cells. × 340



Galaxaura barbata

EXPLANATION OF PLATE V

Galaxaura arborea

FIG. 1–2. Section of portion of thallus, showing cortical cells and assimilators. × 225

FIG. 3. Interior surface view of cortical cells, showing connection with medullary filaments. × 150

FIG. 4. Young assimilators at apical parts of branches. × 225

FIG. 5. Extended assimilatory filaments at base of proliferations. × 160

G. stupicaulis

FIG. 6–8. Young assimilators, showing connections with medullary filaments. × 225

FIG. 9. Section of portion of thallus. × 225

G. spathulata

FIG. 10. Short assimilators. × 225

FIG. 11–12. Section of portion of thallus, showing cortical tissue and assimilators. × 225

G. apiculata

FIG. 13. Terminal cells without apiculi. × 225

FIG. 14. Young assimilators, with apiculate terminal cells. × 225

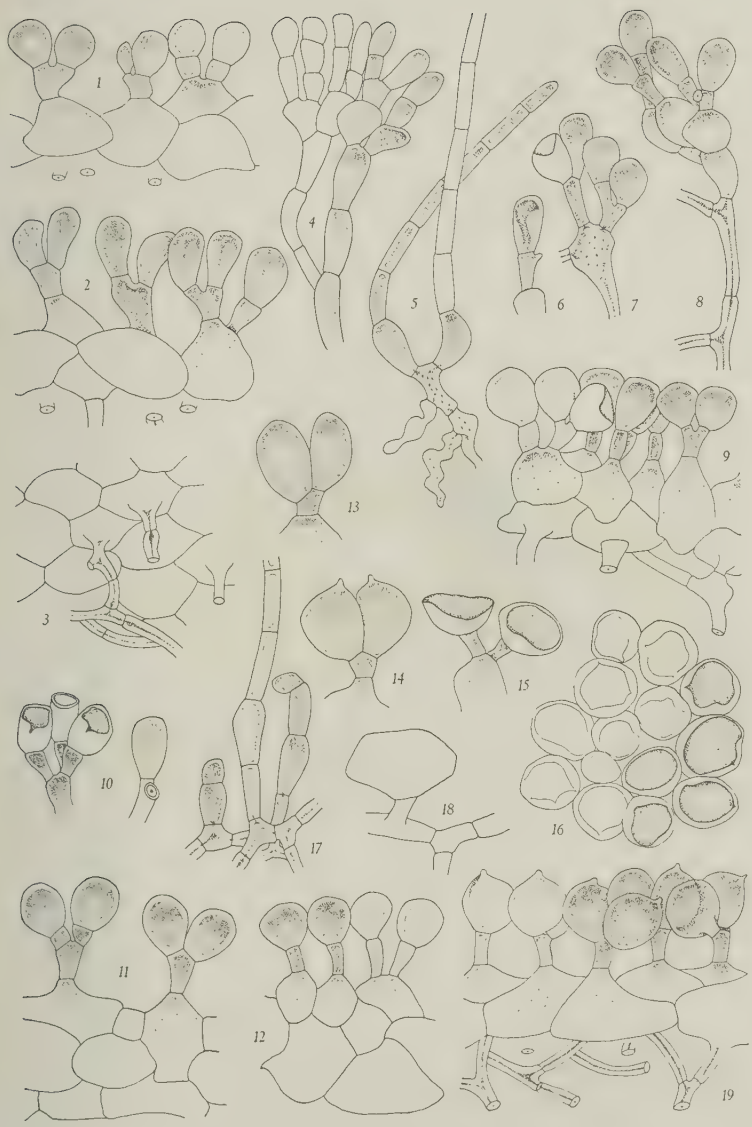
FIG. 15. Old assimilators. × 225

FIG. 16. Assimilators, surface view. × 225

FIG. 17. Extended assimilatory filaments from base of proliferations. × 150

FIG. 18. Inner cortical cell in connection with medullary filament. × 225

FIG. 19. Section of portion of thallus. × 225



Galaxaura species

EXPLANATION OF PLATE VI

FIG. 1. *Galaxaura filamentosa*, sp. nov.; type specimen. × 1

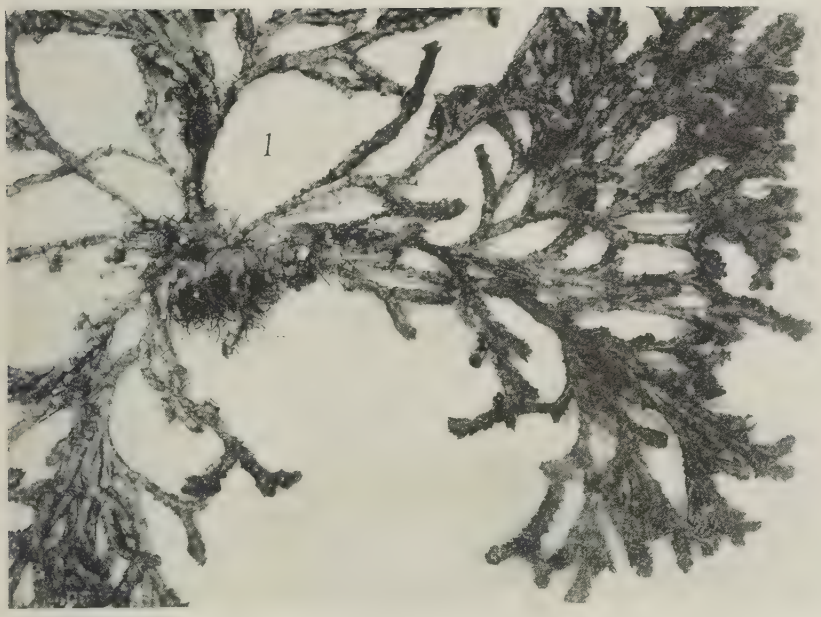
FIG. 2. *G. barbata*, sp. nov.; type specimen. × 1.5

Galaxaura species

EXPLANATION OF PLATE VII

FIG. 1. *Galaxaura ramulosa;* Taylor no. 34–505, Jicarita Island, Panama. × 1.4

FIG. 2. *G. subverticillata;* Villaflores no. 7A, Mindoro, Philippines. × 2.2

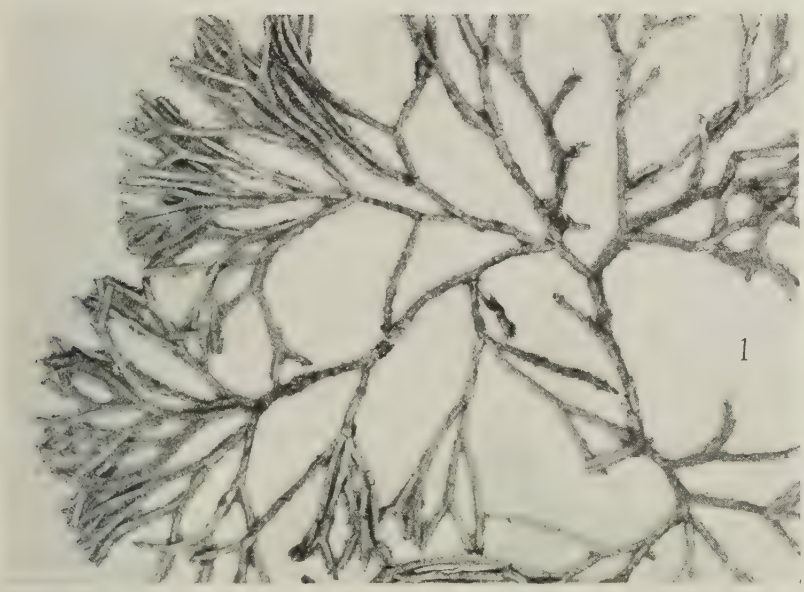


Galaxaura species

EXPLANATION OF PLATE VIII

FIG. 1. *Galaxaura fasciculata;* Kostermans no. 429, Java. × 1.2

FIG. 2. *G. subfruticulosa,* sp. nov.; type specimen. × 1.3

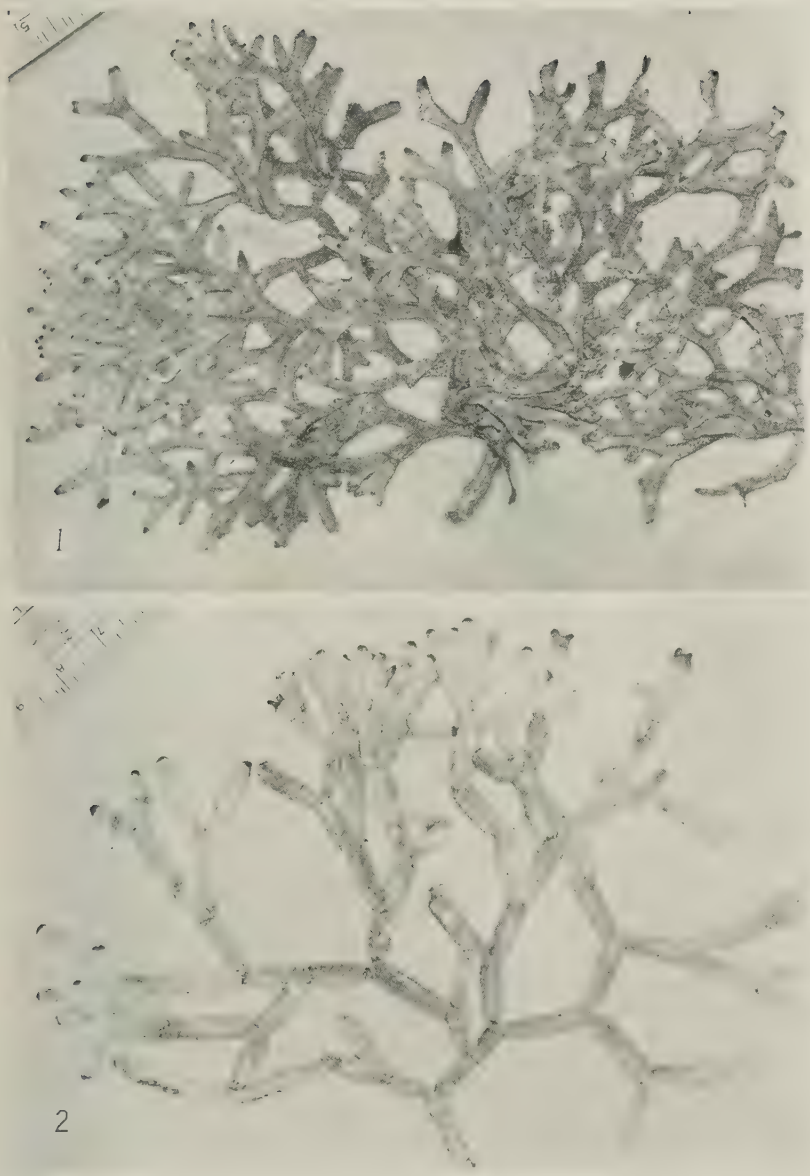


Galaxaura species

EXPLANATION OF PLATE IX

FIG. 1. *Galaxaura apiculata;* Brooks in Taylor's herb. no. 20494, Mukualofa, Tonga. × 0.9

FIG. 2. *G. robusta;* Brooks in Taylor's herb. no. 20444, Mukualofa, Tonga. × 0.8

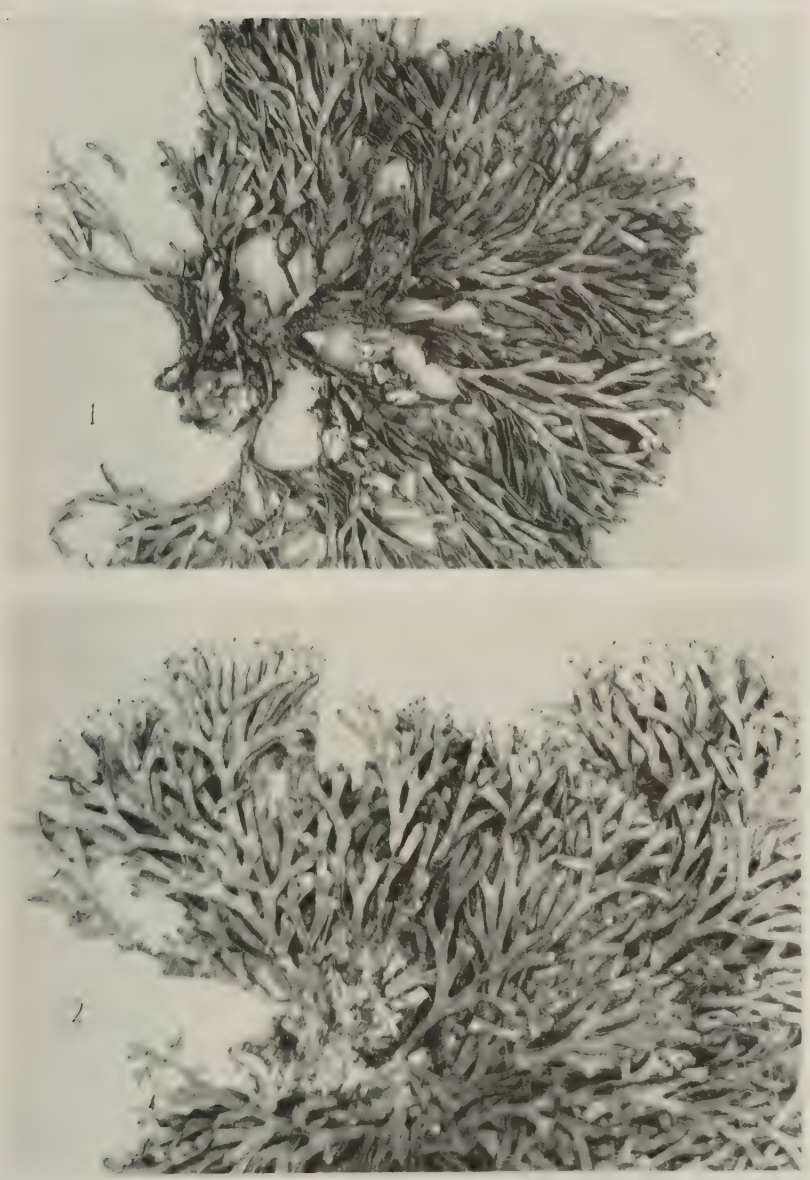


Galaxaura species

EXPLANATION OF PLATE X

FIG. 1. *Galaxaura arborea:* Bartlett no. 15009A. Dalupiri Island, Philippines. × 1

FIG. 2. *G. arborea:* Bartlett no. 14608. Dalupiri Island, Philippines. × 1.1

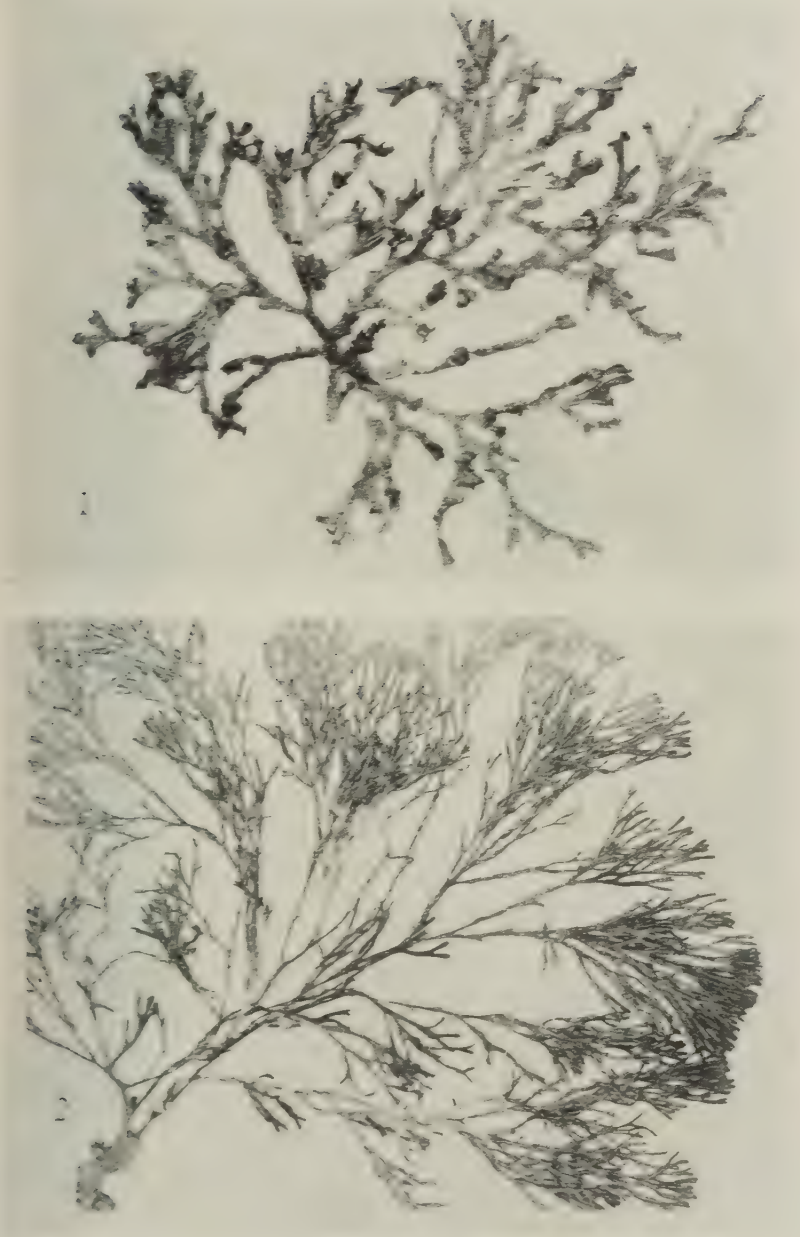


Galaxaura species

EXPLANATION OF PLATE XI

FIG. 1. *Galaxaura stupicaulis;* Taylor no. 39–90A, Golfo Dulce, Costa Rica. × 1.5

FIG. 2. *G. spathulata;* Taylor no. 34–164, Isabela Island, Galápagos Islands. × 0.5



Galaxaura species

NOTES ON THE MICHIGAN FLORA. IX*

OLIVER A. FARWELL †

THE present addition to the series of papers on Michigan flora deals with the extension of ranges, new stations, and the naming of some forms that are worthy of being put on record systematically.

List of Species

Woodsia alpina (Bolton) S. F. Gray. — Two more stations have been found for this rare fern, making four in all on the Keweenaw Peninsula. Keweenaw Co.: Esrey Park, no. 12222½, Sept. 25, 1939; Lac La Belle, no. 12097, Aug. 16, 1939.

Woodsia Cathcartiana B. L. Robinson. — Also rare on the Keweenaw Peninsula. In crevices of rocks. Keweenaw Co.: West Bluff, no. 12153, Sept. 5, 1939; Lookout Mt., no. 12395, July 3, 1940, and no. 12697, Aug. 27, 1940.

Woodsia oregana D. C. E. — In crevices of rocks, on faces of bluffs. Lac La Belle, Keweenaw Co., nos. 12096, 12097½, Aug. 16, 1939.

Potamogeton praelongum Wulf. — The first time I have ever found it, though it is said to occur throughout the state. In Lake Manganese, Keweenaw Co., no. 12581, Aug. 6, 1940.

Potamogeton capillaceum Poir. — This species will take the place of *P. diversifolium*, now excluded from Michigan, unless on reëxamination Lyon's material proves to contain it.

Potamogeton porcatus Muhl. (*P. Spirillus Tuckerm.*). — Arthur Bennett, *Journal of Botany*, 28 (1890) : 297, states that a specimen from Muhlenberg, labeled by himself as his *P. porcatum*, is in the herbarium of Sir J. E. Smith. Since species are now typified by specimens, this plant directly from Muhlenberg must stand as the type of his species. Bennett says it is *P. Spirillus*

* All the previous papers in this series are to be found in the following Michigan Academy publications: *Reports*, 20 (1918) : 161–195; 21 (1919) : 345–371; 22 (1920) : 177–185; *Papers*, 1 (1921) : 85–100; 2 (1922) : 11–46; 3 (1923) : 87–109; 23 (1937) : 123–134; 26 (1940) : 3–20.

† Died September 18, 1944.

Tuckerm.; hence it must supersede Tuckerman's name. In ponds at North Cliff, Keweenaw Co., no. 458, Aug. 20, 1886.

Calamagrostis neglecta (Ehrh.) Gaertn. — This species of reed grass is said to be rare in Michigan. It is listed by Beal in *Michigan Flora* (1904) and by Hitchcock in his *Manual of Grasses* (1935); but Stebbins excludes Michigan from the range of the species in his "Revision of Some North American Species of Calamagrostis," *Rhodora*, 32 (1930) : 53–56. Among the conglomerate on shores of Lake Superior east of Eagle Harbor, Keweenaw Co., no. 12564, Aug. 6, 1940.

Deschampsia caespitosa (L.) Beauv. var. glauca (Hartm.) Hartm. This variety is smaller than the species in all its parts and has involute leaves. On rocky shores. Rare. Near Eagle Harbor, Keweenaw Co., no. 12534, July 30, 1940.

Deschampsia flexuosa (L.) Trin. In rocky woods, sandy places, and open ground; in dry places, whereas the preceding species is one of wet places. Very abundant. Cliff Mine, Keweenaw Co., no. 12426, July 8, 1940. Little Traverse Bay, Houghton Co., no. 12028, July 28, 1939.

Poa paludigera Fern. & Wieg. Near springs and in wet woods. Keweenaw Co.: Gay, no. 12061, July 28, 1939; Cliff Mine, no. 12427, July 8, 1940.

Nardus stricta L. — Mat grass. A second station in Michigan has been found for this European grass. Since it covers a rather large stretch of lowland near the highway and comprises a colony of several hundred stools, it would appear to have been here for a number of years. Lake Linden, Houghton Co., no. 12783, Nov. 3, 1940.

Carex siccata Dew. — In dry fields and on sandy hills. West Bluff, Keweenaw Co., no. 12374, June 28, 1940. Previously collected as follows: Ypsilanti, Washtenaw Co., no. 5457, May 30, 1920; Oakland Co.: Orion, no. 987, May 30, 1895; Parkedale Farm, no. 2656, June 9, 1912; Bloomfield Hills, no. 5225, June 5, 1919; due west of Bloomfield Hills, no. 7911, June 1, 1927.

Carex scirpoides Schk. var. capillacea (L. H. B.) Fernald (*C. Howei* K. K. M.). Keweenaw Co.: in a peat bog near Eagle Harbor, no. 12511, July 30, 1940; in rich woods at Copper Harbor, no. 12600, Aug. 6, 1940.

Carex laricina K. K. M. In peat bogs and swampy shores of

lakes. Shores of Rice Lake, Houghton Co., no. 12410, July 8, 1940. Keweenaw Co.: Meadow Mine, no. 12505, July 30, 1940; Eagle Harbor, no. 12507, July 30, 1940.

CAREX FESTUCACEA Schk. — In the *North America Flora* Mackenzie does not give Michigan in the geographical distribution of this species. He made the determination of my collection, but did not see it in time to include Michigan in its range. Temperance, Monroe Co., no. 8004, July 13, 1927.

CAREX MOLESTA K. K. M. — Identifications by Mackenzie. A segregate from *C. brevior* (Dew.) K. K. M. Rockwood, Wayne Co., no. 4940, June 16, 1918. Monroe Co.: Dundee, no. 5294, July 15, 1918; La Salle, no. 5817, June 2, 1921; Stony Creek, no. 5823, June 9, 1921; South Rockwood, no. 5861, June 14, 1921, and no. 5919, July 12, 1921.

CAREX BREVIOR (Dew.) K. K. M. — Open dry soil or sand. Harris, Oakland Co., no. 5081, July 13, 1918. Woodville, Newaygo Co., no. 5958, Aug. 4, 1921; near Lake Glazon, Keweenaw Co., no. 11801, Aug. 29, 1938.

Var. PSEUDOFESTUCACEA O. A. F. — In moist ground. Algonac, St. Clair Co., no. 5500a, June 20, 1920.

CAREX BICKNELLII Britt. — In dry soil. Oakland Co.: Bloomfield Hills, no. 5225, June 5, 1919; Royal Oak, no. 5578, Aug. 12, 1920; Goodison, no. 7676, Sept. 30, 1925. Ypsilanti, Washtenaw Co., no. 5457a, May 30, 1920.

CAREX BACKII Boott. — In dry woods on bluffs; very scarce. Cliff Mine, Keweenaw Co., no. 12431, July 8, 1940.

CAREX CAPILLARIS L. — On bluffs; rare. Cliff Mine, Keweenaw Co., no. 1824½, Aug. 4 to 11, 1904.

Var. ELONGATA Olney. — Taller with remote spikes. Rare. Mackinac Island, Mackinac Co., no. 967, June 20, 1895. Among conglomerate on shores east of Eagle Harbor, Keweenaw Co., no. 12568, Aug. 6, 1940.

JUNCUS INFLEXUS L. — Very abundant along the highway near Hancock, where it was discovered in 1936 by F. J. Hermann, who says that the only other station for this European species in North America is in New York. Superficially it looks like *J. Balticus*, but the inflorescence is more condensed, and the plant is densely caespitose and glaucous. Quincy Hill, Houghton Co., no. 12735, Sept. 17, 1940.

Juncus tenuis Willd. var. Billingtonii O. A. F. — In this variety the inflorescence is reduced to an umbel of two to five subequal rays, each terminated by a single flower; in appearance it is somewhat like that of *Juncoides carolinae* (S. Wats.) O. K. In moist soil near Lake Linden, Houghton Co., no. 11789, Aug. 21, 1938.

Var. uniflorus O. A. F. — In this variety the inflorescence is reduced to a single sessile flower. Lake Linden, Houghton Co., no. 11790, Aug. 21, 1938.

Juncus canadensis J. Gay. var. **paradoxa,** var. nov. — *Inflorescentia omnino prolifera.* The inflorescence is reduced to proliferous buds. Occasional, on shores of Rice Lake, Houghton Co., no. 12726, Sept. 3, 1940.

Juncus brachycephalus (Engelm.) Buch. — Beal, in *Michigan Flora*, gives only four citations, all for the southern part of the Lower Peninsula. It is found occasionally in the Copper Country. Houghton Co.: shores of Torch Lake, no. 11476, Aug. 11, 1936; Laurium, no. 11485, Aug. 14, 1936; on the Quincy Hill, no. 12756, Oct. 8, 1940. Gay, Keweenaw Co., no. 12061, July 28, 1939.

Unifolium bifolium (L.) Greene. — In the Copper Country this species is called "wild lily of the valley." The typical pubescent variety was found during 1940. This collection extends the range throughout the state. Keweenaw Co.: shores of Lake Bailey, no. 12330, June 23, 1940; shores of Lake Superior near Devil's Washtub, no. 12346, June 23, 1940.

Var. ovale (Ph.) O. A. F. subvar. **hirtellum,** subvar. nov. — *Planta pilosa.* The whole plant is more or less pubescent. In the Copper Country this variety with broadly oval leaves and overlapping basal lobes is easily distinguishable from the narrow-leaved varieties. Keweenaw Co.: shores of Lake Bailey, no. 12331, June 23, 1940; shores of Lake Superior, near the Devil's Washtub, no. 12347, June 23, 1940.

Ranunculus Flammula L. var. filiformis (Mx.) Hook. — A slender plant with filiform stems and leaves creeping in mud of lake shores. Rice Lake, Houghton Co., no. 12722, Sept. 3, 1940. Lake Manganese, Keweenaw Co., no. 12588, Aug. 6, 1940.

Capnoides aureum (Willd.) O. K. — A low diffusely branching herb with many-flowered racemes of golden-yellow flowers. Along

roadsides; rare. Canal, Houghton Co., no. 9625, May 20, 1934; Esrey Park, Keweenaw Co., no. 12354, June 23, 1940.

SAXIFRAGA VIRGINIENSIS Mx. — This species was seen and collected in 1940, the first time since 1883. *Gray's New Manual* (1908), p. 446, describes the leaves as obovate or oval-spatulate and the follicles as purplish; the *North American Flora*, 22 (1905) : 141, as ovate, oval, or oblong and the follicles as mainly green. The latter I take as the type. Exposed rocks and hillsides. Keweenaw Co.: Cliff Mine, no. 22, June 18, 1883; Lookout Mt., no. 12704½, Aug. 27, 1940. The species described in *Gray's New Manual* may be known by the following varietal name.

Var. **cuneata,** var. nov. — *Foliis cuneatis-obovatis vel spatulatis.* Leaf cuneately obovate or spatulate. Exposed rocks. Lookout Range, Keweenaw Co., no. 12254, June 13, 1940.

FRAGARIA GRANDIFLORA Ehrh. — Found in open woods near Lake Superior. Evidently an escape from cultivation. Near Cat Harbor, Keweenaw Co., no. 12457, July 16, 1940.

ROSA BLANDA Ait. var. HERMANNI Erlan. — Swampy grounds. Near Eagle Harbor, Keweenaw Co., no. 11866, Oct. 6, 1938. Near Bear Lake, Houghton Co., 12743, Sept. 17, 1940.

PRIMULA MISTASSINICA Mx. — On wet rocky shores. The *P. farinosa* of Beal's *Michigan Flora* is the *P. intercedens* Fernald, *Rhodora*, 30 (1928) : 86, already reported upon. The *P. mistassinica* is divided, and a new variety is established by Fernald, *op. cit.*, p. 91. The type is more frequent than the variety. Keweenaw Co.: near the Devil's Washtub, no. 12345, June 23, 1940; Sand Bay, no. 12448, July 16, 1940.

Var. *noveboracensis* Fern. — Sand Bay, Keweenaw Co., no. 12440, July 16, 1940.

GALEOPSIS TETRAHIT L. forma **alba,** forma nov. — *Floribus albis vel incarnatis-variegatis.* The corolla is white or variegated with pink. In the typical variety of the species the flowers are purplish. In waste places and in moist open woods. Houghton Co.: shores of Lake Roland, no. 10238, Aug. 13, 1934; Lake Linden, no. 11681, Aug. 5, 1937, and no. 12616, Aug. 11, 1940. Keweenaw Co.: Bete Grise Bay, no. 12107, Aug. 16, 1939; Eagle Harbor, no. 12677, Aug. 20, 1940.

MENTHA PIPERITA L. var. SUBHIRSUTA Benth. — This variety has the underside of the leaves and the stems more or less pubescent. Eagle Harbor, Keweenaw Co., no. 12668, Aug. 20, 1940.

Collinsia parviflora Dougl. — Blue-eyed Mary. A large plant much and diffusely branched, four to nine inches high. On exposed rocky bluffs. Keweenaw Co.: West Bluff, no. 11319, July 14, 1936; Mt. Brockway, no. 11966, June 23, 1939; Lookout Mt., no. 12280, June 13, 1940.

Var. **simplex,** var. nov. — *Plantis humilioribus simplicibus.* Similar to the species but low, usually one or two inches high, rarely up to three and one-half inches, and unbranched. Similar situations. Keweenaw Co.: on dry hills near Cliff Mine, no. 322, Aug. 16, 1885; Lookout Mt., no. 12266, June 13, 1940.

Plantago lanceolata L. var. irrigua Dene. — Similar in appearance to the next species, but the scapes are shallowly and irregularly ten- to twelve-striate or channeled. L'Anse, Baraga Co., no. 10885, July 7, 1935. Lake Linden, Houghton Co., no. 10962, Aug. 4, 1935.

Plantago altissima L. — Scapes up to three feet in height, deeply five-channeled, alternating with five sharply acute angles. In fields, Lac La Belle, Keweenaw Co., no. 12469, July 23, 1940.

Campanula uliginosa Rydb. — Blue marsh bellflower. Not in Beal's *Michigan Flora;* to the best of my knowledge this is the first report of its occurrence in Michigan. In wet meadows. Keweenaw Co.: Meadow Mine, no. 12495, July 30, 1940; Cat Harbor, no. 12608, Aug. 8, 1940.

Solidago hispida Muhl. var. tonsa Fern. — This variety is found on dry, exposed soil. Original range was given as Newfoundland, Quebec, and New Brunswick. It is now found in Michigan; on Lookout Mt., Keweenaw Co., nos. 12706 and 12710, Aug. 27, 1940.

Solidago longipetiolata Mack. & Bush. — Along roadsides in copses. Extends the range eastward from Minnesota. Quincy Hill, Houghton Co., no. 12739, Sept. 17, 1940.

Iva Xanthiifolia Nutt. — Along roadsides; dwarf plants under a foot in height. Quincy Hill, Houghton Co., no. 12758, Oct. 8, 1940.

Lake Linden, Houghton County
Michigan

ADDITIONS TO THE FLORA OF MICHIGAN. V

CLARENCE R. HANES

ONE of the collections listed in the present paper was by H. R. Becker of Climax; another, by F. W. Rapp, of Vicksburg. The rest were made chiefly in 1942 and 1943 by Mrs. Florence N. Hanes and the writer. All plants are from Kalamazoo County, Michigan. Specimens of most of these have been deposited in the herbaria of the Bailey Hortorium, Harvard University, the University of Michigan, and the National Arboretum, at which institutions their identity has been confirmed.

An asterisk is used to indicate those species which are, so far as is known, new to Michigan.

List of Species

*Calamovilfa longifolia (Hook.) Scribn. — On the Grand Trunk railroad right-of-way, six miles southwest of Schoolcraft in Section 32, Prairie Ronde Township, August 1, 1936, no. 226.

C. longifolia is adventive in Michigan. It comes from the Great Plains. Our native grass that grows on sand dunes and beaches along Lake Michigan is *C. longifolia* var. *magna* Scribn. and Merr. The branches of the panicle of the Great Plains plant are nearly erect, with the spikelets usually white or greenish white, whereas in our native plant the branches are widely spreading, with the spikelets usually purple. L. H. Shinners has discussed this species in the *American Midland Naturalist.*[1]

*Muhlenbergia racemosa (Michx.) BSP. — Along the Grand Trunk railway two miles east of Schoolcraft in Section 21, Schoolcraft Township, September 7, 1943, no. 4316.

Professor Fernald[2] has shown that most of the herbarium

[1] Shinners, L. H., "Notes on Wisconsin Grasses — III," *Am. Mid. Nat.*, 29: 779–782. 1943.

[2] Fernald, M. F., "Five Common Rhizomatous Species of Muhlenbergia," *Rhodora*, 45: 231–237. 1943.

specimens passing under the name of *M. racemosa* are really *M. alba* (Linnaeus) Desr. M. racemosa is not common, grows preferably in marshy meadows, while *M. racemosa* is a western species of dry regions. The two species strongly resemble each other.

The grass has found favorable conditions along the railway. It is its dry and well to quite short, and so tough that the section men have a very poor job in mowing it. It has been here for several years and is gradually spreading.

"Agrostis interrupta Scribn. and Ball. — In sandy soil in well-drained field in Section 8, Hayes Township, September 5, 1942, no. 1942.

This grass was well scattered over a part of the field. Associated with it were *Andropogon* and *Calamovilfa*.

"Carex crawfordii Fernald. (= *C. B. Clarke* var. *crawfordii* Fern.) — Near the lower shore on the southeast side of Austin Lake, August 28, 1933, no. 933, in a sandy field near Eagle Lake, Texas Township, August 6, 1941, no. 1941.

We have also found this variety on the east shore of Austin Lake and in a sandy field south of Sugarloaf Lake. The species *C. squalorea* (L.) C. B. Clarke has been collected in at least three different localities in Kalamazoo County. At the best it has crowded annual specimens, which the variety does not have. Our limited experience shows the plants of the species to be much smaller than those of the variety.

"Carex stricta Lam. — In the lane on the M. F. Thomas property, Schoolcraft, July 4, 1943, no. 436.

This probably is not native but a weed that has come to grow used — as evening as F. J. Hermann says: "First noticed [illegible] for Michigan."

"Chenopodium standleyanum J. var. *pinnatifidum* Fern. f. *standleyanum* (Aellen) Fern. — Swamp in Section 33, Climax Township, June 18, 1941, no. 1941; [illegible] grassy meadow in Section 8, Hayes Township, June 14, 1942, no. 1942.

This is a rare form of *Chenopodium* subgenus *Morocarpus*. We have examined scores of plants in all parts of Kalamazoo County and have found specimens of the glandular form in only these two places. Many collections were not more exact.

"Chenopodium standleyanum J. var. *leiocarpum* Fern. — Sandy

wood in Section 29, Oshtemo Township, June 11, 1943, no. 4317.

Though we have collected several specimens of this variety from widely separated sections of the county the plant from Oshtemo Township is the most typical. Our determination was confirmed by Professor Fernald.

*Rubus uvidus Bailey.[3] — Swamp east of the railway station at Vicksburg, August 3, 1942, F. W. Rapp, no. 6203.

This new species of blackberry has been found so far in only the one location. It runs about under bushes and is associated with more erect varieties.

*Rubus meracus Bailey.[4] — On a poplar-wooded slope near a marsh, one and one-half miles southeast of Alamo, June 26, 1939, no. 439.

Only one station has been discovered for this new species. It is a long-running plant resembling somewhat *R. flagellaris* Willd.

*Rubus Schoolcraftianus Bailey.[5] — Type station in an oak wood in Section 30, Pavilion Township, August 3, 1942, no. 1717.

L. H. Bailey published this new species of the Flagellares group in March, 1943. It was named by him in honor of Henry Rowe Schoolcraft, from whom our own village of Schoolcraft received its name. Although previously undescribed, this bramble should not be rare in Michigan since we have collected it at one or more stations in Alamo, Comstock, Kalamazoo, Oshtemo, Pavilion, Schoolcraft, and Texas townships.

Our experience with *R. Wheeleri* shows how the genus Rubus has been neglected. In 1940 we reported before the Michigan Academy [6] one station in Kalamazoo County for this blackberry. It was near Hampton Lake in Portage Township. Since then we have found the species at three other locations in Portage Township, two in Climax Township, three in Schoolcraft Township, and four in Texas Township. In our county *R. Wheeleri* is among our commonest species of Rubi.

*Epilobium hirsutum L. — In low ground one and one-half miles northeast of Portage, August 5, 1943, H. R. Becker, no. 4362.

The flowers of this species are large and showy like those of *E. angustifolium*. It differs from that species, however, in that

[3] *Gentes Herbarum*, V : 304. 1943. [4] *Ibid.*, p. 357. [5] *Ibid.*, pp. 330–332.
[6] Hanes, Clarence R., "Additions to the Flora of Michigan. III," *Pap. Mich. Acad. Sci., Arts, and Letters*, 26 (1940) : 22. 1941.

the pubescence is greater, the leaves are serrulate, sessile, and clasping, and the bracts subtending the pedicels of the flowers are of greater length.

*Solidago graminifolia (L.) Salisb. var. remota (Greene) Harris (*S. remota* (Greene) Friesner). — Pine Island Lake, September 14, 1935, no. 3215; Austin Lake, August 22, 1942, no. 5342.

This goldenrod is quite common on the sandy shores of Austin, Eagle, and Pine Island lakes and in some places on the east border of Bishop's Bog, in Section 28, Portage Township. We did not realize that the species was rare until we sent specimens to R. C. Friesner and L. H. Shinners, both of whom knew of no records for Michigan. I quote Dr. Shinners: "So far as I am aware, this [goldenrod] has previously been known only from the Indiana dunes. Quite distinct. Another plant belonging with the '*Coastal Plain*' element; whether actually connected with the Coastal Plain or not, the term signifies a definite group of midwestern plants with distinctive ranges."

*Centaurea diffusa Lam. — In an uncultivated field on the south boundary of Section 35, Richland Township, July 23, 1943, no. 433.

More than twenty plants occupied a small area of the field. Intermingled with them was the quite common relative *C. maculosa*. To the present this plant has been reported from only a few stations in the United States, but its weedy nature will soon make it more plentiful. Professor Fernald confirmed the determination given above. Dr. Blake stated that it was the nearest to *C. diffusa*.

Schoolcraft, Michigan

"ROOT NODULES" ON ZINNIA PRODUCED BY NEMATODES *

KENNETH LESTER JONES

ON OCTOBER 15, 1943, while preparing a flower bed for the setting out of tulips, I noticed that all the Zinnia plants (six) had root galls (Pl. I, Fig. 1). They had shown no outward sign of disease. Plants of the genera Ageratum, Pelargonium, and Gladiolus in the same bed had no growths on their roots.

I assumed that the galls were of nematode origin, although I had not previously seen any which were so much like bacterial nodules. Since illustrations of similar galls on other genera occur frequently in the literature (e.g. Goodey, 1933, p. 103; Fred, Baldwin, and McCoy, 1932, pl. 5), they are probably common. The roots were washed, wrapped in wax paper, and placed in a refrigerator. The following day the galls were dissected for nematodes. Curiously, none were found, but, instead, small rod-shaped or clavate bacteria abounded and could oftentimes be seen within the parenchymatous cells. The galls were firmly cellular, not decaying.

The surfaces of some galls were sterilized in a 2 per cent mercuric chloride solution and flamed in alcohol. Suspensions of the contents of individual galls in sterile water were plated in nitrogen-free mannitol agar and in the same medium (Fred and Waksman, 1928), with 0.1 per cent $NaNO_3$ added. The cultures were incubated at 28° and 16° C. Results were very similar on all plates, although the rate of growth was less at the lower temperature and in the absence of nitrogen. Over 95 per cent of the colonies have the following characteristics: diameter 5 mm., shape circular, margin entire, elevation convex, surface smooth and glistening, colorless or whitish, and texture slimy to gummy. The bacteria from these colonies were actively motile, gram-negative rods 0.5–1.5 μ in length, occurring singly or occasionally in pairs. A few colonies on the plates were

* Papers from the Department of Botany of the University of Michigan, No. 739.

obviously of a different origin and for the most part proved to be endospore-forming bacilli. Only one actinomycete colony appeared.

The predominant bacterium was isolated and its cultural characteristics studied. It resembles very closely the description in *Bergey's Manual* (1939, p. 97) for *Alcaligenes radiobacter*, although there is also some similarity to the closely related Rhizobium. The characteristics are as follows:

Small rods. — Average size 0.5 by 1.3 μ, occurring mostly singly but occasionally in pairs. Actively motile, gram-negative.

Nutrient gelatin stab. — No liquefaction. Surface growth grayish and thick. A slight growth occurs throughout the length of the stab.

Nutrient broth. — Very slight surface growth of small colonies. Broth faintly turbid and also some large tufts of a whitish growth, which later form a sediment.

Litmus milk. — Serum zone with pellicle developing in one week; alkaline; no ropiness; a brown color appears in two weeks.

Nitrates. — No reduction.

Sugars. — No acid or gas in dextrose, lactose, sucrose, or mannite. A very thick, slimy pellicle forms and the medium usually becomes more alkaline.

Indol. — Not formed.

Growth occurs within twelve days at 16° C. (but not at 28° C.) in special media more alkaline than pH 11 (Hofer, 1935).

This saprophytic bacterium is a frequent contaminant in legume inoculants (Hofer, 1935). *Bergey's Manual* (1939) places it in the family Rhizobiaceae and states that its "inability to produce crown galls or root nodules distinguishes this organism from *Phytomonas tumefaciens* and *Rhizobium spp.*"

Galls were fixed in formalin-acetic acid-alcohol and the sections stained with gentian violet. Preliminary study of these revealed bacterial strands — apparently mostly of a slime, which made staining of the microbes difficult — extending into the galls in a tortuous manner from the periphery. They were too wide to be confused with infection threads of a bacterial nodule. Otherwise the tissue was free of microörganisms. However, further examination revealed nematode larvae at the ends of clear tunnels; backward some distance toward the exterior of the gall these tunnels were filled with the bacterium and its slime (Pl. I, Fig. 2[1]). Nematodes were thus the primary invaders and no doubt produced the galls. Their specific identity is difficult to determine since only larvae and eggs have been observed.

[1] The photograph was taken by Professor C. A. Arnold.

Alcaligenes radiobacter had found these tunnels particularly inviting and for some reason had taken them over practically to the exclusion of other microbes. Kostoff and Kendall (1930) believe that in tobacco galls nutrients accumulate in the vicinity of the worms because a toxic secretion discharged by them increases the permeability of the cortical cells. It would seem that these bacteria thrive on such materials and perhaps on the exudates of the worms. They were present in cells lining the tunnels, which resembled the granular giant cells figured by Kostoff and Kendall. Secondary invaders have been reported for other nematode galls. Muir and Henderson (1926), as reported by Goodey (1933, p. 110), "found a fungus always associated with tissues invaded by the parasite, and when cultured this fungus gave the same colour as the discoloured roots." Němec (1911) reported that dead syncytia are invaded by fungi and bacteria, and Triffitt (1931) observed hyphae of *Colletotrichum atramentarium* in rootlets attacked by *Heterodera schachtii*. I do not know how frequently root galls form in Zinnia. I find no mention of them in the literature, and plants friends brought to me from several gardens failed to show these structures.

SUMMARY

Healthy Zinnia plants from one garden all possessed root galls apparently produced by nematodes. The tunnels of the nematodes and the cells lining them were practically filled with one saprophytic bacterium, the slime producing *Alcaligenes radiobacter*.[2]

UNIVERSITY OF MICHIGAN

[2] Thirty-six Zinnia plants were grown in the same flower bed in 1944, and only one developed root galls. The soil had not been altered or treated in any way.

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FIG. 1. "Root nodules" (galls) on Zinnia, produced by nematodes

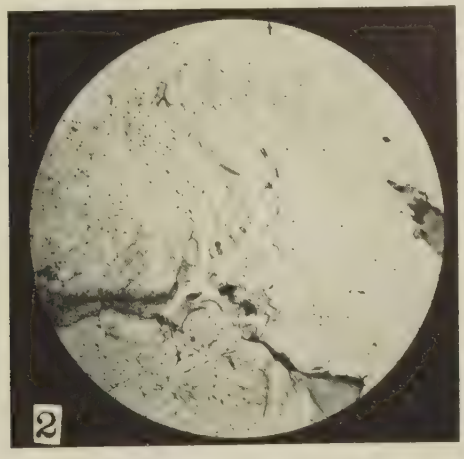

FIG. 2. Interior of a gall, showing two nematode larvae at the ends of clear tunnels. The darkened material filling the outer portions of the tunnels is a slime produced by a secondary invader, *Alcaligenes radiobacter*

A MONOGRAPH ON THE GENUS CYSTODERMA *

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THE genus Cystoderma was established by Fayod (1889) to include certain agarics placed in the tribe Lepiota of Agaricus by Fries (1821). Fayod listed *Lepiota amianthina*, *L. granulosa*, *L. cinnabarina*, *L. carcharias*, *L. seminuda*, and *L. fumoso-purpurea* as belonging in it and *L. Georginae* as a possible additional species. As the name indicates, he placed greatest emphasis on the character of the universal veil. The other characters he mentioned, such as the differentiated cortex and pith of the stipe, the fragility of the lamellae, and the branching of the hyphae forming the subhymenium, are not recognized as significant in distinguishing genera among the gill fungi. The regular gill trama and the spore characters are important, but as given by Fayod they do not separate Cystoderma from Lepiota.

Fayod's genera were disregarded for many years, no doubt in part because they were based on morphological and anatomical studies which could be made only with the use of a microscope, and in part because of the great popularity of the Friesian system and the general acceptance of it throughout the world. However, as microscopic characters began to assume a major rôle in the classification of agarics, it became apparent that Fayod, in spite of many errors, had charted the course modern studies of agarics were to take, and his work has recently been receiving more attention.

Since Fayod listed *L. amianthina*, *L. granulosa*, *L. cinnabarina*, and *L. carcharias* first, it is obvious that these should be regarded as typifying the genus, and *L. amianthina* is here recognized as the type.

* Contribution from the Herbarium of the University of Michigan and from the Laboratory of Cryptogamic Botany and the Farlow Herbarium, Harvard University.

Of the other species he listed, *L. seminuda* and *L. Georginae* have free gills, and it appears best to retain them in Lepiota. *L. fumoso-purpurea* is apparently the same as *Agaricus echinatus* Fr. and therefore must also be excluded.

From the time of its publication down to the present Cystoderma has had a varied history. Many investigators disregarded it. Konrad and Maublanc (1924–37) recognized it as a genus in the Tricholoma series. In their definition they characterized it as lacking cystidia. Earle (1909) recognized the genus, but defined it as having free gills. He listed *L. amianthina*, a species with attached gills, as the type. Kühner and Maire (1934) recognized it as a genus, but later Kühner (1936) included it in Lepiota, part in his section Granulosae (*L. granulosa*, etc.) and part, *L. seminuda* and its relatives, in the Micaceae. Lange (1935) had considered it a subgenus of Lepiota, but excluded *L. seminuda*. Singer (1939) used Kühner's 1936 concept, but recognized it as a genus consisting of the two sections mentioned above. The section Micaceae of Kühner, in addition to *L. seminuda*, contains *L. Bucknallii*, *L. Hetieri*, *L. Eyrei*, and *L.* (*Agaricus*) *echinata*. We have excluded the Micaceae from Cystoderma because the species in this section have free gills, or, at the most, the gills become only secondarily attached to the stipe and are very readily separated from it. Another character which is mentioned in the literature is that in Lepiota the stipe is readily separable from the pileus, whereas in Cystoderma the stipe and the pileus tissues are confluent, and, consequently, the two do not separate readily. We have not checked this character on fresh material to determine whether an anatomical difference in this respect actually exists between the groups in question, and so we have not emphasized the character here.

Kauffman (1923) transferred many of the species here placed in Cystoderma to Armillaria, but this disposition of them has not helped in clarifying the status of the latter genus. Investigators have long been aware of the difficulties of recognizing the genus Armillaria in the Friesian sense, and various arrangements have been made for its species (see Kauffman, 1923). Singer (1939) recognized Catathelasma (= Biannularia), Armillariella, and Armillaria, besides placing some species such as *A. focalis*, *A. caligata*, and *A. cingulata* in Tricholoma. Whatever disposition is made of the Friesian genus Armillaria, it must be admitted that the species of Cystoderma stand out as a group not closely related to any other group in Armil-

laria, so that we prefer to treat them separately rather than as one of several unrelated subdivisions in a highly artificial genus.

In none of the works mentioned above has there been any attempt to treat critically the species of Cystoderma from a single region or to monograph them. Most investigators have assumed that the group was composed of *C. granulosum*, *C. cinnabarinum*, *C. amianthinum*, and *C. carcharias*, and since all these were supposedly well-known fungi, the need for critical studies did not seem urgent. We must acknowledge here that we approached the study of the group with much the same attitude, with the result that our observations in the field were limited more or less to times when other fungi were not demanding our undivided attention. However, attempts to identify the North American species continually brought the senior author to the realization that there were some unsolved problems in the genus. Consequently, this joint critical study was eventually undertaken for the purpose of reclassifying the species, if possible, on the basis of characters more reliable than those emphasized in the Friesian classification.

ACKNOWLEDGMENTS

We wish to express our appreciation to Dr. H. D. House, state botanist, New York State Museum, for the opportunity of studying the collections of Dr. Charles H. Peck. These collections are deposited in the New York State Museum, Albany, New York. Through the kindness of Professor E. B. Mains, director of the University of Michigan Herbarium, we had access to the notes and collections of C. H. Kauffman, the unpublished illustrations of L. C. C. Krieger, and also other materials pertinent to this study. Dr. David H. Linder, curator of the Farlow Herbarium, Harvard University, permitted us to inspect the material deposited in the Farlow Herbarium, including that collected by W. G. Farlow. We are also indebted to Professor H. M. Fitzpatrick, Cornell University, Ithaca, New York, who permitted us to examine authentic material of *Lepiota rhombospora* Atkinson from the Atkinson Herbarium. Dr. J. Walton Groves, of the Division of Botany and Plant Pathology, Department of Agriculture, Ottawa, Canada, made available to us the collections in the mycological herbarium of that department. Dr. S. M. Zeller, Oregon State College, Corvallis, Oregon, allowed us to examine his collections, which are important because of the long-

standing interest he has had in the genus. Dean L. R. Hesler, of the University of Tennessee, turned over to us the collections in the Herbarium of the University of Tennessee. These are of special interest not only because of a new species discovered among them, but also because of range extensions, which we were able to verify. To Mr. Maurice B. Walters, of Cleveland, Ohio, to Mr. William B. Gruber, of Portland, Oregon, and to Dr. D. E. Stuntz, University of Washington, Seattle, Washington, we are under obligation for both collections and photographs.

DEFINITION AND LIMITS OF THE GENUS

Spore deposits white; spores smooth, ellipsoid to subglobose or ventricose to subrhomboid, either amyloid or nonamyloid; pleurocystidia and cheilocystidia sometimes present; gill trama typically regular to subregular, hyaline to pale cinnamon in KOH, nonamyloid; pileus trama with the cuticle formed by chains of inflated cells (sphaerocysts) or the cells ellipsoid to cylindric or quite irregular in some, the walls either hyaline, olivaceous, or strongly yellowish to cinnamon or russet in KOH, smooth or with an incrusting pigment, clavate-pedicellate cells sometimes present in the cuticle in addition to the sphaerocysts; subcuticular hyphae filamentous but in some species with a KOH reaction similar to the sphaerocysts (when the subcuticular hyphae show a strong KOH reaction a larger percentage of clavate to cylindric cells are usually present in the cuticle); flesh hyaline to cinnamon in KOH, the hyphae regularly with clamp connections; lamellae regularly attached to the stipe, adnate, adnexed, sinuate, or subdecurrent, sometimes seceding; stipe confluent with the pileus and sheathed with a coating of sphaerocysts or enlarged ellipsoid cells similar to those forming the cuticle of the pileus, or the sheath made up of an inner layer which is fibrillose to membranous and with the chains of sphaerocysts thinly coating its outer surface; annulus either present and flaring as well as quite persistent or evanescent to scarcely forming; habitat either terrestrial or lignicolous; stipe fleshy and centrally attached.

Type species: *Agaricus amianthinus* Scop. ex Fries, Hymen. Eur., p. 37. 1874.

The definition given above excludes the species of Tricholoma which lack clamp connections, all species of Lepiota with free gills,

and the species of Tricholomopsis. The last do not have sphaerocysts making up the cuticle of the pileus. In the light of the results of our investigation the arrangement proposed by Konrad and Maublanc (1924–37) has much to recommend it. These authors placed Cystoderma in the Tricholoma series. Further studies on the relationship of Cystoderma to Tricholomopsis (*T. rutilans*, *T. decora*, and others) are needed, but the similarities between the species of Cystoderma and those in Lepiota also having sphaerocysts that make up the cuticle of the pileus should not be considered merely accidental. The clarification of this problem rests in part on whether or not the separable pileus of the species of Lepiota can be demonstrated to be an important difference and in part on further critical studies of some of the poorly known species of Lepiota. The white spore deposit at once distinguishes Cystoderma from all gill fungi with colored spores which have a somewhat similar universal veil. *Phaeolepiota aurea* (Fr.) Maire (*Pholiota aurea* of the Friesian system) is the most likely to be mistaken for a species of Cystoderma, and we have included it in our key as an aid to its quick identification. It has the appearance of a gigantic *C. granosum* and, indeed, was described as a Lepiota by Quélet. The color of the spore deposit also distinguishes the genus Cystoderma from Naucoria. In fact, a possible intermediate species is *C. rhombosporum*, which has spores of the same peculiar shape as those in some of the ocher-spored agarics, and the same type of cheilocystidia, but lacks the incrusting pigment usually present on the hyphae of the cuticle of the pileus in that group, and, as it is described, has colorless spores in deposits. It needs further study from fresh material, but in the dried condition does not appear to be referable to any known species in the ocher-brown-spored series. The development of chains of sphaerocysts in the universal veil of one species of Deconica, *D. tomentosa* Murrill, has recently come to the attention of the senior author. It is interesting to see this character present in groups of fungi with such different spores, and one is reminded once again that the same characters have arisen independently in various groups of gill fungi. At least there appears to be no close relationship between the Deconica mentioned and either Cystoderma or Naucoria. This situation complicates the study of relationships between groups of agarics and makes us reluctant at present to do more than suggest possibilities.

COMMENTS ON THE CHARACTERS OF THE SPECIES

The synonymy of the European species will illustrate the history of the group. Most of the species now recognized were at first included under the old name *Agaricus* (*Lepiota*) *granulosus*. Murrill (1914) listed all the known North American species as synonyms of *Lepiota amianthina*. The failure of investigators properly to evaluate the species in this group can be traced in large measure to the characters imposed upon them by the Friesian system. Such characters as the color of the pileus, the attachment of the gills, the degree to which the annulus develops, and the nature of the scales over the lower part of the stipe are variable to the extent that they have caused great confusion in the differentiation of species by those who attempted to recognize more than one. We have amply established this point as a result of studying the specimens identified by many previous investigators. One of the reasons for our finally undertaking this study was the confusion we found when trying to compare our own identifications with those of others. It was apparent from the start that a satisfactory classification could be arrived at only by the use of characters not previously widely employed.

The use of the iodine reaction of the spores in Cystoderma as introduced by the French mycologists, particularly Kühner and Maire (1934), furnished the first and most important character in erecting a new and more usable as well as a more natural classification of the genus. They found two series of species existing in the group: one with nonamyloid spores containing *C. cinnabarinum*, and one with amyloid spores containing *C. amianthinum*, *C. carcharias*, and *C. haematites*. We have verified the importance of this character in our studies and have used it to divide the genus into two sections.

A second important character was soon discovered during the course of studying herbarium specimens. When revived in alkaline solutions the cuticular and subcuticular cells and hyphae of some species assume a strong cinnamon, reddish, or deep rusty-brown color. In others no reaction is observed; in one an olive-gray reaction was discovered. We have found these reactions to be distinct enough to justify grouping the species in the sections according to their reactions in alkaline solutions. Spore characters have been used to recognize species or varieties, depending on the degree of difference found. In the *C. amianthinum* series, because of the number of

intermediate units present, spore size has been made a varietal distinction. The same is true for the KOH reactions of the flesh of the pileus and the gill trama. Either these tissues do not react or the color produced is faint and variable in different gills or parts of the pileus. The important point to bear in mind here is whether or not any distinct color reaction is observed in any of the tissues concerned. A number of sections must be examined, and the sections must be thin enough to allow the details of the gill trama to be observed.

Contrary to the statement by Konrad and Maublanc (1924–37), cystidia are known in Cystoderma, and we have placed emphasis upon their type, if present, and on whether cheilocystidia are present or absent. We have used the presence of cheilocystidia as the deciding character by which *C. cinnabarinum* is distinguished from large forms of *C. granulosum*. This emphasis on cystidia is in keeping with that placed upon it throughout the classification of white-spored agarics. Variability in the number present is found here, however, as elsewhere in the gill fungi. In *C. cinnabarinum* we have occasionally collected carpophores in which both pleurocystidia and cheilocystidia were very abundant, and others in which pleurocystidia were rare to scattered or apparently absent. In *C. granosum* cheilocystidia of the clavate type are characteristic. In *C. rhombosporum* they are the usual fusoid-ventricose type, but in *C. amianthinum* only occasional cheilocystidia occur. So far as our present information goes, they are too rare to be considered a valuable taxonomic character.

The attachment of the gills, the color of the pileus, the taste and odor of fresh material, the degree to which the annulus develops, and the habitat are all secondary characters, and are the ones that were too variable for purposes of precise classification. These are not without value in isolated instances, however. The habitat and the degree of development, along with the persistence of the annulus, are useful in conjunction with the iodine and KOH reactions. In *C. granosum* habitat appears to be constant and distinctive, whereas in *C. amianthinum* it is not. The annulus in *C. carcharias*, *C. granosum*, and *C. fallax* is membranous and usually persistent; it furnishes a good field character in spot identification. The attachment of the gills needs to be critically studied in relation to the iodine and KOH reactions. It may prove to be fairly constant and helpful

in the field. We have used the color of the pileus and sheath of the stipe to distinguish forms when they are not correlated with other significant differences. In most species we have found it rather variable, but in *C. granosum*, *C. fallax*, and *C. subvinaceum* it appears, from the information available, to be quite constant.

COMMENTS ON THE ARRANGEMENT OF THE SPECIES

Certain very distinct evolutionary trends are evident within the genus, and it is upon these that we have based our classification. The most primitive species is *C. Ambrosii*. This is evident from the nonamyloid spores, the relatively abundant filamentous hyphae present among the chains of sphaerocysts in the cuticle of the pileus, and the lack of a distinctive KOH reaction by the cells of the cuticle. Next in the nonamyloid series we have placed *C. granulosum*, with its variants. They are distinguished from *C. Ambrosii* by the positive reaction to KOH by the cuticle of the pileus and by their brighter or their darker colors. *C. ponderosum* is placed next after *C. granulosum* because of the apparent reduction in the formation of sphaerocysts and the failure of those formed to separate from one another readily. We consider this a retrogression because in *C. granulosum* and its forms a tendency toward the reduction of sphaerocysts and greater differentiation of the subcuticular hyphae was noted. *C. ponderosum* is thus regarded as a branch of the *granulosum* series. The latter is continued in *C. cinnabarinum* and *C. australe*. The cheilocystidia of these species indicate that they have attained a higher level of development than the others. Apparently both have been derived from *C. granulosum*. *C. rhombosporum* is placed at the end of the series. Because of the lack of a distinctive KOH reaction in the subcuticular cells of the pileus some might be inclined to consider it a branch from *C. Ambrosii*. Its cheilocystidia and spores indicate, however, a higher level of development, and since the KOH reaction of the subcuticular hyphae of *C. cinnabarinum* is not so strong as in *C. granulosum* and since it is almost lacking in *C. australe*, we may assume that in Atkinson's species the character has retrogressed still further.

In the second series are grouped species having amyloid spores. *C. carcharias* is placed at the bottom because of the negative reaction of the cuticle in KOH. *C. pulveraceum* is placed above it because of the lignicolous habitat and because many of the cuticular cells

show further differentiation in the form of a filamentous apical proliferation. *C. caucasicum* is arranged after *C. pulveraceum*. It shows colored cuticular elements in alkaline solution and is thus closer to *C. amianthinum*, which is represented by a large aggregate of forms. There is a rather wide range in spore size, as well as considerable difference in the intensity of the coloration, and the species is further characterized by the almost complete suppression of cylindric or elongated cells in the cuticle of the pileus. *C. fallax* is distinguished by its consistently smaller spores, generally darker colors, and more persistent annulus, and appears to occupy an intermediate position between *C. amianthinum* and *C. granosum*. *C. granosum* is placed at the end of this series by virtue of its size, cheilocystidia, and habitat.

We have placed *C. haematites* with *C. subvinaceum* in the third series because of its resemblance, at least superficially. We have no data on the KOH reaction of the cuticle of its pileus. This series is characterized by the olivaceous-gray color assumed by the cuticular cells when treated with KOH and is based on *C. subvinaceum*. It may have been derived from *C. carcharias*.

In the following account fourteen species are recognized in Cystoderma. Five new ones, *C. caucasicum*, *C. australe*, *C. fallax*, *C. ponderosum*, and *C. subvinaceum*, are described. In *C. amianthinum* a new variety, var. *sublongisporum*, and a new form of var. *typicum*, *f. olivaceum*, are proposed along with var. *occidentale* in *C. granulosum*. During the course of our study we have been able to establish the occurrence in North America of twelve of the fourteen species. *C. haematites* and *C. caucasicum* are the two exceptions. The former is known only from Europe (England, France, and Italy), and the latter only from the Caucasus Mountains. *C. amianthinum* var. *longisporum* has not been reported in North America, and *C. granulosum* var. *occidentale* as well as *C. amianthinum* var. *sublongisporum* are varieties not known outside North America. Six of the species have been found in Europe. To this number *C. fallax* should perhaps be added, since Kühner and Maire (1934) have commented on a puzzling agaric which appears to be this fungus.

Information concerning the distribution of the species is still incomplete. In general, however, it can be said that the common species such as *C. amianthinum*, *C. granulosum*, and *C. cinnabarinum* are circumpolar in distribution since they are known from Europe,

Asia, and North America. *C. granulosum* and *C. amianthinum* have been reported from Japan by Imai (1938), and the latter apparently also occurs in Australia as *Armillaria muscicola* (see Cleland, 1934). Maire (1937) has reported *C. amianthinum* and *C. granulosum* from Morocco in North Africa.

GENERAL CONSIDERATIONS

The techniques used in the study were the standard procedures now current in the study of gill fungi. The iodine tests were made with Melzer's reagent, which is composed of equal parts (20.0 gr. each) of chloral hydrate and water, 1.5 gr. of KI, and 0.5 gr. of iodine crystals. The KOH reactions were obtained with a 2.5 per cent solution. This is the customary reagent employed to revive sections of dried material.

In the paragraphs listing material studied the following abbreviations are used:

CU = Cornell University, Ithaca, New York.
FH = Farlow Herbarium, Harvard University, Cambridge, Massachusetts.
L = Cryptogamic Herbarium of the Academy of Science, Leningrad, U.S.S.R.
MO = Mycological Herbarium of the Department of Agriculture, Ottawa, Canada.
NY = New York Botanical Garden, New York City.
NYS = Herbarium of the New York State Museum, Albany, New York.
UM = Herbarium of the University of Michigan, Ann Arbor, Michigan.
UT = Herbarium of the University of Tennessee, Knoxville, Tennessee.
UW = Herbarium of the University of Washington, Seattle, Washington.
Z = Herbarium of S. M. Zeller, Oregon State College, Corvallis, Oregon.

KEY TO SPECIES

I. Spore deposit yellowish; carpophore rich ochraceous brown ; large, terrestrial; annulus flaring and membranous ..... *Phaeolepiota aurea*
II. Spore deposit white
  A. Spores nonamyloid
    1. KOH not coloring the cuticular cells of the pileus or, if so, only a pale yellowish tint developing ..... 1. *C. Ambrosii*
    2. KOH causing the cuticular cells to become tawny to deep rusty brown or reddish
      a) Spores ellipsoid to subglobose
        (1) Subcuticular and cuticular cells not with conspicuous incrusting pigment (pigment in the cell wall instead)
          (a) Cheilocystidia absent ..... 2. *C. granulosum*
          (b) Cheilocystidia present
            (i) Terrestrial, large, and fleshy; cap usually cinnabar red to orange ..... 4. *C. cinnabarinum*

(ii) Lignicolous, small, cap rusty brown; southern in distribution ..... 5. *C. australe*
(2) Subcuticular and cuticular cells with an incrusting pigment as seen when revived in KOH ..... 3. *C. ponderosum*
b) Spores subrhomboid to ventricose-apiculate . 6. *C. rhombosporum*

B. Spores amyloid
1. KOH not coloring the cuticular cells (see also 2 and 3)
a) Terrestrial; cuticular cells not with a filamentous proliferation ..... 7. *C. carcharias*
(1) Pileus slightly colored pinkish to lilaceous ..... f. *typicum*
(2) Pileus white ..... f. *album*
b) Lignicolous; cuticular cells sometimes proliferated 8. *C. pulveraceum*
2. KOH coloring the cuticular cells tawny to reddish or rusty (see 3 also for *C. haematites*, for which no KOH reaction is known)
a) Pigment brownish and dissolved in the cell sap in at least some cells (NH_3 mounts of dried material) ..... 9. *C. caucasicum*
b) Pigment located in the cell walls
(1) Spores usually 5 μ or more long 10. *C. amianthinum* and varieties
(2) Spores usually shorter than 5 μ
(a) Pileus 2–5 cm. broad; terrestrial, usually under conifers; cheilocystidia none ..... 11. *C. fallax*
(b) Pileus 4–9 cm., bright orange; clavate cheilocystidia present; on decaying hardwood logs . 12. *C. granosum*
3. KOH coloring the cuticular cells olivaceous gray
a) Gills unchanging when bruised; flesh of pileus and stipe pallid; on decaying wood ..... 13. *C. subvinaceum*
b) Gills white, becoming reddish when bruised. Flesh pale liver color, yellowish in stipe; terrestrial ..... 14. *C. haematites*

SECTION I: GRANULOSA A. H. Smith and R. Singer, Sec. Nov.

Sporis haud amyloideis.

1. Cystoderma Ambrosii (Bres.), comb. nov.

Armillaria Ambrosii Bresadola, Fung. Trid., 1 : 27. 1881.

Illustrations: Bresadola, Fung. Trid., Vol. I, pl. 31; Icon. Mycol., pl. 50.

Pileus 4–5.5 cm. broad, broadly convex to nearly plane, surface dry and at first more or less covered with small white conic scales formed by tufts of fibrils and enlarged cells, in age more or less glabrescent or appearing cottony-fibrillose, snow white over all when young, in age flushed sordid tan (near "cinnamon buff"); flesh thick over the disc, tapered abruptly near the margin, whitish, odor

none, taste mild; lamellae close, 85 ± reach the stipe, 2–3 tiers of lamellulae, broad (up to 4–5.5 mm.) next to the stipe, tapered to the margin, adnate, becoming adnexed in age, whitish or tinged cream color, edges even, no color change noted on bruised portions; stipe 5–9 cm. long, 8–12 mm. thick, solid, equal, pallid within, surface white and more or less fibrillose to lacerate-scaly up to the apical zone left by the thin more or less fibrillose veil, in age somewhat glabrescent.

Spores ellipsoid, smooth, nonamyloid, 4–5 × 2.5–3 μ; basidia four-spored, 22–28 × 4–5 μ; pleurocystidia and cheilocystidia not differentiated; gill trama of interwoven hyphae, nonamyloid, lactiferous hyphae intermingled; pileus trama floccose beneath a surface layer of loosely arranged chains of globose to sausage-shaped thin-walled cells 18–80 × 18–50 μ, filamentous hyphae intermingled, all hyaline to very slightly yellowish in KOH, tramal body nonamyloid, clamp connections abundant.

Habitat. — Under larch in mossy places or under alder in mixed alder, cedar, and Douglas fir forests. Very rare.

Distribution. — Originally described from northern Italy but also found along the Santiam River, Cascade Mountains, Oregon. The area occupied by this species still remains to be delimited.

Material studied. — Smith, 18185 (FH, UM), Oct. 31, 1941. Santiam River, Oregon.

Observations. — The nonamyloid spores and the presence of a comparatively large number of filamentous hyphae in the tissue making up the veil are here considered primitive characters and, consequently, the species is placed at the bottom of the evolutionary series. It appears significant that these characters are correlated with negative KOH reactions on the cuticular and subcuticular cells. This fungus is most easily confused with *C. carcharias* f. *album* (see page 103), but is easily distinguished by the larger number of filamentous hyphae in the cuticle of the pileus and by the nonamyloid spores.

2. *Cystoderma granulosum* (Batsch ex Fr.) Fayod, Ann. Sci. Nat., Ser. 7, 9 : 351. 1889.

(*a*) Var. *typicum* f. *typicum*

Agaricus granulosus Batsch ex Fries, Syst. Mycol., I : 24. 1821.
Agaricus granulosus subsp. *ferruginea* Fries, Monogr. Hymen. Suec., 1 : 29. 1857.

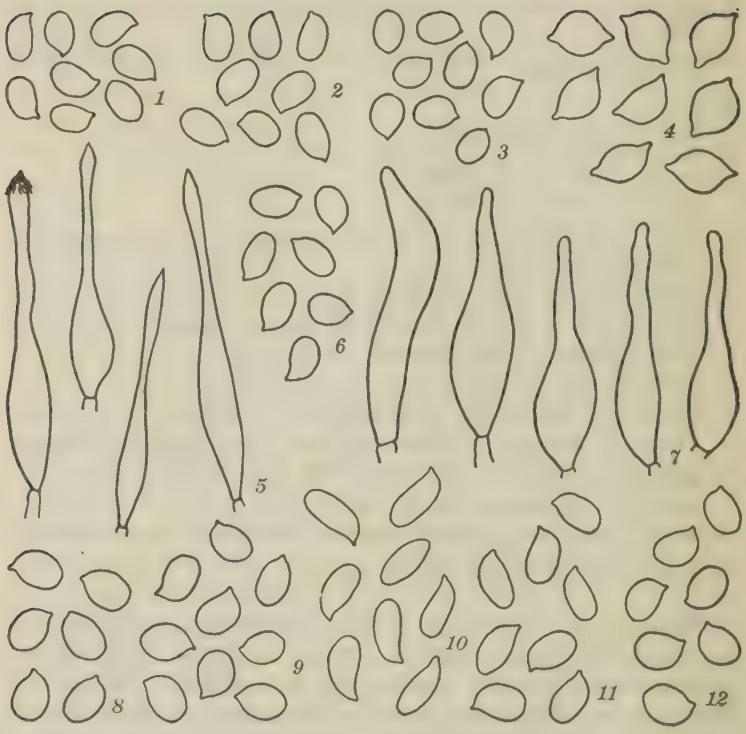
Lepiota granulosa S. F. Gray, Natural Arrangement of British Plants, 1 : 602. 1821.

Armillaria granulosa Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 2 (1922) : 60. 1923.

Illustrations:

Plate I; Text Figure 1, spores.
Barla, Champ. Alp. Mar., pl. 16, figs. 5–8.
Batsch, Elench. Fung., fig. 24.
Bischoff, Kryptog., fig. 3464.
Bresadola, Icon. Mycol., pl. 599.
Britzelmayr, Hymen., pl. 1, fig. 2, and f. *sphagnorum*, pl. 111, fig. 569 (color somewhat too yellow).
Cooke, Illus. Brit. Fungi, no. 39, pl. 18.
Dufour, Atlas des Champ., pl. 7, fig. 12.
Farlow and Burt, Icones Farlowianae, pl. 10 (upper figures).
Gillet, Champignons qui croissent en France, pl. 44.
Hahn, Pilzsammler, fig. 9.
Harzer, Naturgetreue Abbildungen der Pilze, pl. 44, fig. A.
Hussey, Illus. Brit. Mycol., Vol. I, fig. 45.
Krombholz, Naturgetreue Abbildungen und Beschreibungen der essbaren, schädlichen und verdächtigen Schwämme, pl. 1, fig. 2.
Patouillard, Tab. Anal. Fung., fig. 611.
Ricken, Die Blätterpilze, Vol. II, pl. 81, fig. 3.
Saccardo, Mycologiae Venetae Specimen, tab. 4, figs. 15–19, as var. *cortinata* (probably not *C. granulosum*).
Sicard, Hist. Nat. Champ., tab. 24, fig. 127.

Pileus 1.5–3 (4) cm. broad, ovoid to convex when young, broadly campanulate to plane, with or without an obtuse umbo in age, margin at first incurved slightly and appendiculate with the veil remnants, surface dry and granular-furfuraceous or covered with small conic granulose scales, even or radially wrinkled, color variable, sometimes evenly colored but often darker on the disc, russet to tawny, the margin paler and yellowish ("russet," "tawny," "ochraceous tawny," "ochraceous buff," or between "orange cinnamon" and "mikado brown"), usually dull reddish cinnamon when dried ("mikado brown" to "Sayal brown"), often with a hoary sheen, at times pallid vinaceous cinnamon; flesh thin, equal, whitish or flushed pale rufous, odor not distinctive, taste mild; lamellae adnexed and rounded next to the stipe or adnate with a decurrent tooth, close, broad and at times somewhat ventricose, white to pale yellowish or subconcolorous pallid away from the edges, not darkening appreciably in drying, edges even; stipe usually rather short in relation to the width of the cap, 2–4 (6) cm. long, 2.5–6 mm. (longer and up to 10 cm. in sphagnum), equal or slightly enlarged downward,



FIGURES 1–12

Spores and cystidia of Cystoderma

FIG. 1, spores of *C. granulosum* var. *typicum* f. *typicum;* FIG. 2, spores of *C. granulosum* var. *adnatifolium;* FIG. 3, spores of *C. ponderosum;* FIG. 4, spores of *C. rhombosporum;* FIG. 5, cheilocystidia of *C. cinnabarinum;* FIG. 6, spores of *C. cinnabarinum;* FIG. 7, cheilocystidia of *C. rhombosporum;* FIG. 8, spores of *C. fallax;* FIG. 9, spores of *C. carcharias;* FIG. 10, spores of *C. amianthinum* var. *sublongisporum;* FIG. 11, spores of *C. amianthinum* f. *typicum;* FIG. 12, spores of *C. granosum*

The drawings were made with the aid of a camera lucida, and as reproduced those of the spores are approximately 1,650 times natural size and of the cystidia 750 times.

stuffed to hollow, pallid within, surface granulose-scaly to the evanescent pallid fibrillose apical annular zone or merely furfuraceous, concolorous with pileus below the annular zone, whitish and silky above.

Spores white in deposits, 3.5–5 × 2.5–3 μ, ellipsoid, smooth, nonamyloid; basidia four-spored, 18–20 × 5–6 μ; pleurocystidia and cheilocystidia none; gill trama hyaline in KOH, homogeneous, the hyphae more or less regularly arranged; pileus trama with a cuticle of chains of cells 10–50 × 10–25 μ, some globose and up to 20 μ in diameter, some subglobose to ellipsoid and up to 50 × 25 μ, some more or less cylindric, with smooth brown walls when revived in KOH, the filamentous hyphae beneath the inflated cells also with rusty-brown walls in KOH, the hyphae progressively paler toward the gill trama, clamp connections present.

Habitat. — Scattered to gregarious on moss and soil under hardwoods as well as conifers. It usually fruits during the late summer and fall and is not uncommon.

Distribution. — This species is very widely distributed throughout north temperate regions. In Europe it is known from U.S.S.R., Finland, Sweden, Germany, Austria, Czechoslovakia, France, Italy, Spain, and England, and also from North Africa. In Asia it has been found in the Caucasus and Altai Mountains. In North America it has been collected in Nova Scotia, Quebec, Ontario, and Manitoba in Canada, and in the United States it occurs across the continent from Maine to Washington and south to Tennessee and Oregon.

Material studied. — Collections of fresh material have been studied as follows: Singer, Huntington Wild Life Forest, Newcomb, New York, Sept., 1941, 98 (FH); also material from the Caucasus and Altai Mts. of Asia and from various regions of the European part of the U.S.S.R. (L), and from Austria, France, and Spain. Smith, Rock River, Michigan, Sept. 12, 1929 (UM); Colchester County, Nova Scotia, 1931 (UM); Ann Arbor, Michigan, Oct. 1, 1933, 33–1049 (UM); Blue River, Oregon, Oct., 1937, 7919 (UM), 8075 (UM); Milford, Michigan, Sept., 1940, 18859 (UM).

The following collections of dried material have been examined: Farlow, Shelburne, New Hampshire, Sept., 1891, as *Ag. granulatus* (FH). Hesler, Knox County, Tennessee, Nov., 1941, 14053 (UT). Hotson, San Juan, Nov. 5, 1939, H. Hotson, Washington (UW). Kelly, Indian Point, Magnetawan, Ontario, Canada, Aug. 24, 1921, 1186 (UM). Kauffman, Ithaca, New York, Aug. 24, 1904, as *L. cinnabarina* (UM); Pend d'Oreille National Forest, Copeland, Idaho, Sept. 7, 1922, coll. Wehmeyer (UM); Lake Quinault, Washington, Oct. 31, 1925, coll. and det. Brown as *L. amianthina* (UM). Zeller,

Lincoln County, Oregon, Nov., 1934, coll. Burlingham (UM, Z); Canyonville, Oregon, Oct. 22, 1937 (UM, Z); Kilowan, near Falls City, Oregon, Nov., 1939 (UM, Z); the type of *A. granulosoides* Zeller (UM, Z). The following collections were examined from the Mycological Herbarium of the Division of Botany, Department of Agriculture, Ottawa, Canada: F–7018, Mt. Burnet, Quebec, Sept. 27, 1936; F–7022, Graham's Bay, Ontario, Sept. 18, 1936; F–8765, Norway Bay, Quebec, Oct. 4, 1938; 10974, Burnet, Quebec, Sept. 7, 1942; 11420, Petawawa Forest Experiment Station, Ontario, Aug. 31, 1943; collection by Macoun, Canadian Cryptogams, 1, Beechwood, Ontario, as *L. amianthina*, Sept. 16, 1891.

Observations. — Although one of the supposedly well-known species of agarics, *C. granulosum* is by no means so sharply delimited from its close relatives as one might expect. Consequently, although we have listed the majority of the illustrations which have been published as *C.* (*Lepiota* or *Agaricus*) *granulosum*, we do not insist that they illustrate the species as we have recognized it here. Patouillard's figure 611 is an example. Even with the Patouillard collections available for study it is impossible to be sure that one has examined the actual carpophores from which the illustration was made. The figure in question could easily represent a somewhat rosy fruiting body of *C. carcharias*. The color of *C. granulosum* is quite variable, as is evidenced by the varieties *occidentale* and *adnatifolium*, as well as by the range given for var. *typicum*. Aside from these varieties, one often collects carpophores in various stages of being bleached, and these are at times almost impossible to distinguish from those of f. *albidum*. F. *sphagnorum* Britzelmayr appears to be an exceptionally long-stiped form on sphagnum. We have not seen material of it and are inclined to regard it as a chance variation resulting from the habitat in which it was found. *Laccaria laccata* frequently shows a similar variation. In old weathered specimens sections of the pileus are likely to show very few of the separable globose cells characteristic of fresh young material, and these pilei appear to have the cuticle made up mostly of filamentous hyphae. Such old pilei are the ones which show best the hoary sheen mentioned by Kauffman, and in our estimation they represent the first stages of the bleaching out of the pileus. This may be observed on slowly expanding buttons as well as on mature carpophores. Near Mt. Hood, Oregon, buttons were observed to remain in the unexpanded state for two weeks.

(*b*) Var. *typicum* f. **albidum** (Peck), comb. nov.

Lepiota granulosa var. *albida* Peck, Ann. Rep. New York State Mus., 41 : 82. 1888.

Pileus 1.5–2.5 cm. broad, convex to plane, minutely granulose-scaly, whitish when dried, the scales discolored slightly and brownish, when treated with KOH becoming dark rusty brown; gills moderately close, pallid when dried; stipe short, 2.5–3 cm. long, 3–5 mm. thick, lower portion slightly granulose in dried condition.

Microscopic characters as in f. *typicum*, with the exception that KOH reactions were not so pronounced. The subcuticular hyphae were pale cinnamon, and the few sphaerocysts found were only moderately dark cinnamon.

Habitat. — Scattered to gregarious on humus, in pastures, or on needle carpets under conifers.

Distribution. — New Hampshire, New York, Michigan, and Oregon.

Material studied. — Peck, Catskill Mts., New York, type (NYS); Farlow, Shelburne, New Hampshire, Sept., 1891, as *Ag. granulatus* (FH); Smith, Wilderness State Park, Emmet County, Michigan, Oct. 1934, 1239 (UM). Zeller, Canyonville, Oregon, Oct. 22, 1937 (UM, Z) (?).

Observations. — Zeller described the caps of his material as "putty gray to sand color," but in the dried condition they are indistinguishable from Peck's type. His specimens were also found in the open among grasses. The description given above is drawn entirely from Peck's type in order to avoid any possible confusion. It appears that Peck very probably had a truly persistently whitish form rather than merely faded specimens of f. *typicum*, but it is evident from our study of the material cited that faded collections of f. *typicum* are frequently going to be very difficult to distinguish from his form. It may be impossible to do so when herbarium specimens are not accompanied by proper notes.

(*c*) Var. *typicum* f. **robustum**, f. nov.

A forma typica differt magnitudine *Cystoderma cinnabarinum* in mentem revocante.

Illustrations:
Bresadola, Icon. Mycol., Vol. I, pl. 36.
Konrad et Maublanc, Icon. Sel. Fung., Vol. III, pl. 238.

Pileus 3–9 cm. broad, convex to plane, granulose-scaly, deep brick red ("brick red" to "Hay's russet"), but becoming paler in age, when dried near "Verona brown" (dark sordid vinaceous cinnamon); lamellae crowded, adnate to slightly adnexed; stipe 3–7 cm. long, 8–15 mm. thick, clavate, solid, sheathed with a double sheath up to the flaring more or less persistent floccose to submembranous annulus, the outer layer furfuraceous to scaly and concolorous with the pileus, inner layer pallid to cream color and fibrillose, both layers more or less worn away in age, silky and pallid or tinged pale tan to rufous violaceous toward the apex.

Spores 4–4.5 × 2.5-3 μ, white in deposits, smooth, ellipsoid, nonamyloid; basidia four-spored, 18–20 × 4–5 μ; pleurocystidia and cheilocystidia not differentiated; gill trama with a central portion of strongly interwoven hyphae flanked on either side by a narrow band of more or less parallel hyphae, subhymenium very narrow and not distinctive; all parts hyaline in KOH, pale tawny in iodine; cuticle of pileus of globose to somewhat elongated cells with smooth bright reddish-brown walls in KOH, the cells 10–25 (40) × 10–15 (20) μ, beneath this a region of reddish-brown filamentous hyphae gradually fading into the hyaline flesh toward the gills, these hyphae with incrusting pigment on the walls, clamp connections present.

Habitat. — Scattered to gregarious on humus in mixed forests or in pure stands of hardwoods as well as under conifers. Fall. Rare to uncommon.

Distribution. — In Europe it is known from France and Italy but is probably as widely distributed as the typical form. In North America it has been recorded from Maryland, New York, Michigan, Oregon, and Washington in the United States and from Quebec and Ontario in Canada.

Material studied. — Fresh specimens were studied as follows: Smith, Milford, Michigan, Sept. 15, 1938, 10967 — type (UM); Mt. Angeles, Port Angeles, Washington, Oct. 8, 1941, 17651 (UM); Detroit, Oregon, Oct. 31, 1941, 18196 (UM). The following collections of dried material have also been examined: Kauffman, Seventh Lake, Adirondack Mts., New York, Sept. 21, 1921 (UM). Kelly, Maryland, Aug. 29, 1920, 441 (UM). Zeller, Corvallis, Oregon, Dec. 3, 1934, 9200 (UM, Z). Drayton, Burnet, Quebec, Sept. 20, 1942, Ottawa, 11025 (MO). Odell, Hiawatha Park, Oct. 25, 1920, no number (MO).

Observations. — This form differs from f. *typicum* in attaining the size of *C. cinnabarinum*, and in its consistently more rusty-reddish colors. At times these are bright enough to cause some confusion with var. *adnatifolium*, which appears to be characterized by the more abundant, paler (in KOH) globose cells in the cuticle of the pileus and by a paler subcuticular region. Many collections will probably be difficult to place because of intergradations. Kelly, 441, appears to be intermediate between f. *typicum* and f. *robustum*.

(*d*) Var. **occidentale** A. H. Smith, var. nov.

Pileo 1–3 cm. lato, obtuso demum late convexo, sicco, granuloso, sordide vinaceo, demum avellaneo vel pallide vinaceo-brunneo; lamellis late adnatis vel subdecurrentibus; stipite 30–70 × 3–6 mm., sursum pallide vinaceo, deorsum pileo concolori. Habitatio: inter muscos, locis ambustis autumno. Washington et Oregon in America Boreali.

Pileus 1–3 cm. broad, obtuse with an inrolled margin when young, becoming obtusely campanulate to broadly convex in age, sometimes flattened but with a decurved margin, surface dry and covered with minute conic to subappressed granulose to fibrillose scales, often with only spotlike scales in age, color rusty vinaceous brown to deep sordid vinaceous ("sorghum brown" to "Vandyke brown"), sometimes dull chestnut brown to deep brick color, gradually fading in age and becoming avellaneous or merely a very sordid pale vinaceous brown; flesh whitish to pallid and unchanging, thin, moderately fragile, odor and taste not distinctive; lamellae close to subdistant, 30–38 reach the stipe, 2–3 tiers of lamellulae, broadly adnate to subdecurrent, broadest (3–4 mm.) near the stipe, whitish to pale buff and unchanging when bruised or dried, edges even; stipe 3–7 cm. long, 3–6 mm. thick at the apex, slightly enlarged downward, soon hollowed, at least in the lower portion, pallid within, surface fibrillose-furfuraceous up to a superior fibrillose annular zone, the fibrils pallid and at first forming an almost cortinate veil, sheath concolorous with the scales of the pileus and not breaking up into conspicuous zones or scales, composed of an outer deeply colored more or less furfuraceous layer and an inner pallid fibrillose layer, the latter becoming more conspicuous in age, apex silky and pallid vinaceous at first, when dried having a dull purplish-vinaceous cast.

Spores hyaline in KOH, nonamyloid, 4–4.5 × 2.5–3 μ, ellipsoid,

basidia four-spored, 18–20 × 4–5 μ; pleurocystidia and cheilocystidia not differentiated, gill trama homogeneous, the hyphae parallel to subparallel, hyaline in KOH and dull yellowish tawny in iodine; pileus trama with a more or less differentiated cuticle, the cells on and near the surface more or less globose to ellipsoid and with dark to pale rusty-brown walls in KOH, the enlarged cells 10–40 × 10–20 μ, beneath these occurs a gradual transition to a much-branched tangled mass of filamentous hyphae with rusty-brown walls, the trama proper not distinctly separated from this region (the color of the cell walls merely less intense progressively toward the gills), clamp connections present, the colored hyphae beneath the inflated cells 5–10 (15) μ in diameter.

Habitat. — Gregarious on moss beds of Funaria and Ceratodon in areas where brush has been burned, such as along roads and along the edges of fields. Fall.

Distribution. — The Olympic Peninsula of Washington, south into Oregon.

Material studied. — Smith, Lake Crescent, Washington, Oct. 10, 1935, 3081 (UM); McKenzie Bridge, Cascade Mts., Oregon, Oct. 14, 1937, 7787 (UM); the type, Heart O'Hills, Mt. Angeles, Olympic Mts., Washington, Sept. 28, 1941, 17382 (UM).

Observations. — This variety differs from var. *typicum* in its subdecurrent gills, more vinaceous colors, and in the sheath of the stipe remaining more or less intact. In the field it would probably be confused with *C. haematites* because of the resemblance in color. The habitat may also be distinctive, but this needs verification from a larger number of collections. In the dried condition var. *typicum* and var. *occidentale* are almost inseparable, and old carpophores of both bleach in much the same manner if exposed to the weather for long periods.

(*e*) Var. **adnatifolium** (Peck), comb. nov.

Lepiota adnatifolia Peck, Bull. New York State Mus., 10: 947. 1902.
Armillaria adnatifolia Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 2 (1922): 60. 1923.

Illustration: Figure 2, spores (p. 84).

Pileus 2.5–5 (8) cm. broad, ovoid to convex when young, expanding to broadly convex or plane, at times retaining an obtuse umbo, the margin appendiculate from the remains of the veil, surface

covered by more or less granulose pyramidal scales, scales crowded over the central portion and more widely separated toward the margin; scales either persistent or becoming worn down and somewhat powdery, color bright reddish orange ("English red" to "orange rufous"), surface between the scales paler reddish; flesh thick, at least in the disc, tapered toward the margin, white to pale ferruginous near the surface; lamellae crowded, adnate to slightly adnexed, narrow (3–5 mm.), whitish to pale buff, edges even; stipe 2.5–4 (7) cm. long, 5–10 mm. thick at apex, clavate, solid but at times hollowed in age, glabrous or slightly squamulose below the small often evanescent annulus, pallid or rufescent, silky above and pallid or tinged pale rufous tan.

Spores hyaline in KOH, 3.5–4.4 × 2.3–2.8 (3) μ, smooth, ellipsoid, nonamyloid; basidia 16–18 (20) × 4–4.5 μ, four-spored, hyaline in KOH; pleurocystidia and cheilocystidia none; gill trama hyaline in KOH, with an interwoven central strand flanked by parallel hyphae near the subhymenium, subhymenium very thin, filamentous, and much branched; pileus with a cuticle of chains of globose to subglobose cells, the cells readily separable and 12–25 × 10–20 μ, the walls smooth or faintly rugulose and pale cinnamon in KOH (not deep reddish), subcuticular hyphae more or less filamentous (the change gradual), very pale cinnamon except for the layer giving rise to the chains of cells forming the cuticle, tramal body of hyaline hyphae 4–6.5 μ in diameter and with abundant clamp connections.

Habitat. — Scattered to gregarious under conifers. September and October. Rather uncommon.

Distribution. — Ontario, Maine, New York, Michigan, Wyoming, Idaho, Oregon, and Washington.

Material studied. — The following collections of fresh material have been studied: Mains, Harbor Springs, Michigan, Sept. 14, 1932, 32–760 (UM). Smith, Lake Timagami, Ontario, Sept. 5, 1936, 4554 (UM, University of Toronto Herbarium); Blue River, Oregon, Oct. 17, 1937, 7919 (FH, UM). The following collections of dried material were examined: Hotson, Washington (UW). University of Toronto Herbarium, 11884, coll. Roy F. Cain, York County, Ontario (UT). Kauffman, Lakeland, Michigan, Oct. 11, 1912 (UM); Lake Placid, Adirondack Mts., New York, Sept. 5, 1914, with Mains (UM); Pend d'Oreille, National Forest, Copeland, Idaho, Sept. 7, 12, 1922, with Wehmeyer (UM); Parlin, Canton Point, Maine, Oct. 25–29,

1942, 15332, 15333, 15334, 15402 (all UM). Peck, Hague, and Bolton, Warren County, New York, type (NYS). F–10554, Île Perrot, Quebec, Aug. 27, 1941 (MO); 11047, Petawawa Forest Experiment Station, Sept. 29, 1942 (MO); one unnumbered collection, Wakefield, Ontario, Aug. 12, 1903, as *L. granulosa* (MO).

Observations. — Since the material of the type collection, which was examined by the senior author, did not have cystidia, it became necessary to reclassify Peck's species as a variety of *C. granulosum*. The microscopic data in the description given above are taken from the type. Kauffman's account (1918) applies to *C. cinnabarinum*. The carpophores of var. *adnatifolium* dry a dull to bright orange, whereas those of var. *typicum* are nearer "mikado brown" to "chestnut brown" or, in f. *robustum*, "Verona brown." Var. *adnatifolium* is generally not so robust as *C. cinnabarinum*, but the colors are about the same. The presence of cheilocystidia at once distinguishes the latter.

KEY TO FORMS AND VARIETIES OF *C. GRANULOSUM*

I. Pileus 1–3 (4) cm. broad
  A. Pileus deep vinaceous brown ("sorghum brown" to "Vandyke brown"); gills typically subdecurrent ..... var. *occidentale*
  B. Pileus cinnamon, tawny to russet or yellowish; gills typically notched ..... var. *typicum*
  C. Pileus whitish or white ..... var. *typicum* f. *albidum*

II. Pileus 3–8 cm. broad
  A. Pileus "brick red" to "Hay's russet"; when dried dark sordid vinaceous cinnamon ("Verona brown") .... var. *typicum* f. *robustum*
  B. Pileus "English red" to "orange rufous," when dried pale orange ("apricot buff") ..... var. *adnatifolium*

3. Cystoderma ponderosum, sp. nov.

Illustration: Figure 3, spores (p. 84).

Pileo 4–11 cm. lato, squarroso-squamoso in disco e squamis ochraceo-alutaceis vel argillaceis vel laetius flavido-brunneis, squamis magis appressis sparsioribusque, interstitiis pallidis, textura squamarum vix granulosa, at subfibrillosa et squamis ex ea re satis persistentibus; carne crassa, albida vel pallida, odore et sapore haud notis; lamellis moderate confertis, angustis, late adnatis vel dente decurrentibus, pallide alutaceis, aciebus integris; stipite clavato, 60–80 × 8–15 mm., ad basin albomycelioideo, albo vel albido, sub-

tiliter et fugacissime cothurnato, mox vestimenti fractura zonatulo, zonis subconcoloribus squamis pilei, subfibrilloso supra annulum; sporis 3–3.4 × 2.6–3 μ, late ellipsoideis vel subglobosis, levibus, hyalinis; basidiis 20–24 × 4.6–6 μ, tetrasporis; cystidiis nullis; textura tramali lamellarum ex hyphis parallelis vel intertextis efformata; carne KOH ope haud colorata, ex hyphis intertextis, 4–6 μ crassis, fibuligeris consistente; cuticula pilei ex hyphis 4–6 μ crassis, rubido-fulvis pigmenti incrustantis causa consistente, in squamis autem nonnullis hyphis inflatis praesentibus, at rarissime globosis vel ellipsoideis usque ad 30 × 15 μ metientibus. Habitatio: ad terram muscosam supra saxum; Tennessee, America Borealis.

Pileus 4–11 cm. broad, broadly convex becoming plane, in age the margin wavy, lobed, uplifted in large carpophores in age, surface dry, squarrose-scaly over the disc from "ochraceous buff" to "clay color" or brighter yellowish-brown scales, toward the margin the scales more appressed and widely separated, allowing the pallid ground color to show, the scales more fibrillose than granulose in texture and consequently relatively persistent; flesh thick, whitish to pallid, odor and taste not recorded; lamellae moderately close, narrow, broadly adnate or with a decurrent tooth, near "light buff," edges even; stipe clavate, 6–8 cm. long, 8–15 mm. at the apex, base more or less white-mycelioid, white or whitish, the sheath thin and evanescent, soon broken up into small zones which are more or less concolorous with scales of pileus, annulus poorly formed and evanescent, somewhat fibrillose above the annulus, in largest carpophore distinctly fibrillose-pubescent to the apex, pubescence pallid buff.

Spores 3–3.4 × 2.6–3 μ, broadly ellipsoid to subglobose, nonamyloid, smooth, hyaline in KOH; basidia 20–24 × 4.6–6 μ, four-spored, hyaline in KOH, yellowish in iodine; pleurocystidia and cheilocystidia not differentiated; gill trama hyaline in KOH, parallel to interwoven; flesh of pileus hyaline in KOH, of compactly interwoven hyphae 4–6 μ in diameter, clamp connections abundant; cuticle of pileus composed chiefly of interwoven tawny to russet hyphae 4–6 μ in diameter and both very much branched and very compactly interwoven as compared with other species, the walls with incrusting pigment, the scales with a few enlarged cells present but these seldom spheric or ellipsoid, instead rather somewhat angular or otherwise irregular in shape, the largest about 30 × 15 μ.

Habitat. — On mossy soil on rocks, Mt. Le Conte, Great Smoky

Mountains National Park, Tennessee, July 26, 1942, L. R. Hesler, 14390.

Distribution. — Known only from the type collection.

Observations. — When the scales of the pileus are crushed, all the cells appear to be broken from their attachment and hence cannot be regarded as readily separable as in related species. The color of *C. ponderosum* is very distinct in the dried specimens, though when mounted in KOH the cuticular and subcuticular hyphae of both *C. cinnabarinum* and *C. ponderosum* are quite similar in color, and the more compact arrangement present in the latter as well as the lack of sphaerocysts must be relied upon to distinguish it. Because of the difference in color of dried material it can readily be distinguished from all other species in the genus. This is the one species of Cystoderma that most closely approaches the section Acutesquamosae of the genus Lepiota. In fact, the structure of the cuticle, which is in the nature of trichoderms rather than an epithelium, recalls certain representatives of that section. However, the nonpseudoamyloid spores and the adnate lamellae cause us to consider *C. ponderosum* a true Cystoderma. The lack of cheilocystidia may serve as additional evidence that this species is not a Lepiota.

4. *Cystoderma cinnabarinum* (Alb. & Schw. ex Secr.) Fayod, Ann. Sci. Nat., Sér. 7, 9 : 351. 1889.

Agaricus granulosus cinnabarinus Alb. & Schw. ex Secretan, Mycogr. Suisse, 1 : 60. 1833.

Agaricus (*Lepiota*) *granulosa* subsp. *cinnabarina* Fries, Monogr. Hymen. Suec., 1 : 29 (13 in reprint). 1857.

Agaricus cinnabarinus Fries, Hymen. Eur., p. 36. 1874.

Lepiota granulosa var. *cinnabarina* Gillet, Les Hyménomycètes, p. 71. 1874.

Lepiota granulosa subsp. *cinnabarina* Konrad et Maublanc, Icon. Sel. Fung., Vol. III, pl. 238. 1924–33.

Lepiota cinnabarina Karsten, Hattsvampar, p. 14. 1879.

Armillaria cinnabarina Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 2 (1922) : 60. 1923.

Illustrations:

Figures 5–6, spores (p. 84).
Barla, Champ. Alp. Mar., pl. 16, figs. 1–4.
Boudier, Icon. Mycol., I, pl. 15 (? or *C. granulosum* var. *adnatifolium*).
Britzelmayr, Hymen., pl. 42, fig. 294.
Cooke, Illus. Brit. Fungi, no. 38, pl. 43.
Flora Danica, Fasc. 30 (1823), pl. 1795 (as *Ag. granulosus*).
Hoffmann, Icon. Anal., pl. 13, fig. 1.
Lange, Flora Agar. Danica, pl. 15, fig. F (excellent); also pl. 15, fig. E (as *L. granulosa*).

Pileus 3–6 (8) cm. broad, ovoid when young or at times more or less convex, expanding to broadly convex, sometimes plane or remaining broadly umbonate, surface dry and covered by numerous short-pointed pyramidal scales from the breaking up of the granulose cuticle, the scales fairly persistent and becoming rather widely separated over the marginal area in age as a result of the expansion of the pileus, margin appendiculate at first with fragments of the broken veil, color bright red to bright orange brown with the paler flesh showing between the scales ("English red," "cinnamon rufous" to "ferruginous") over the disc, usually paler over marginal area, sometimes "Sanford's brown" on the disc and "cinnamon rufous" on the margin; flesh thin, pallid or ferruginous near the surface, somewhat watery, odor oily-farinaceous; lamellae bluntly adnate but soon seceding and free, broadest next to the stipe but narrow in relation to the diameter of the cap, close to crowded, thin, white to creamy white, unchanging, edges even to minutely fimbriate; stipe 3–6 cm. long, (6) 8–15 mm. thick at apex, solid, more or less clavate-bulbous and with considerable débris and mycelium adhering to the base, sheathed up to the evanescent annulus with a furfuraceous to granulose sheath similar in color and texture to the scales covering the pileus, with an inner thin pallid fibrillose coating giving the stipe a coarsely fibrillose appearance if the outer colored layer becomes worn away, creamy buff to pale rufous above the annular zone and silky-fibrillose to somewhat pruinose, flesh pallid.

Spores white in deposits, nonamyloid, $3.5–5 \times 2.2–3\ (3.4)\ \mu$, smooth, ellipsoid; basidia $16–24 \times 4–5.5\ \mu$, four-spored or occasionally very few one- to three-spored; pleurocystidia very rare to abundant, $32–46 \times 4–9\ \mu$, basal portion slightly ventricose and tapered to a long narrow neck with a slightly enlarged almost spear-shaped apex which may or may not be slightly incrusted, hyaline and thin-walled; cheilocystidia scattered to abundant, similar to pleurocystidia, about 2–3.5 μ thick in the upper half; gill trama homogeneous, regular, subparallel at first, interwoven in fully expanded caps, hyaline in KOH, subhymenium not distinctive; pileus trama composed of a cuticle of globose (10–35 μ) and more or less elongated ($30–50 \times 10–16\ \mu$) cells, bright reddish brown in KOH, the walls smooth, beneath this layer a region of brown-walled filamentous hyphae, which gradually merges into the hyaline flesh toward the gills, clamp connections present.

Habitat. — Scattered to gregarious on decayed coniferous wood, on needle beds under various species of conifers, under hardwoods on humus, and among mosses such as Rhizidium. It fruits during the late summer and fall, and is fairly common.

Distribution. — This species is known throughout Europe and temperate North America. Singer has collected it in the Altai Mountains of Asia.

Material studied. — The following collections were studied in the fresh condition: Singer, A432, Kurai, July 31, 1937, coll. Singer and Vasilieva (L); Newcomb, New York, Huntington Wild Life Forest, Sept. 16–17, 1941, 99 (FH). Smith, Colchester County, Nova Scotia, Aug. 18, 1931, Wehmeyer, 779 (UM); Lake Crescent, Washington, Oct. 14, 1935, 3148 (UM); Joyce, Washington, Oct. 2, 1935, 2791 (UM); South Fork, McKenzie River, Oregon, Oct. 20, 1937, 7998 (UM); Belknap Springs, Oregon, Oct. 23, 1937, 8135 (UM); Crescent City, California, Oct. 30, 1937, 8253 (UM); Fort Dick, California, Nov. 10, 1937, 8594 (UM); Trinidad, California, Nov. 12, 1937, 8675 (UM); Crescent City, California, Nov. 29, 1937, 8979 (UM); Baker Lake, Washington, Sept., 1941, 16893 (UM).

Dried specimens have been examined as follows: Farlow, Shelburne, New Hampshire, Sept., 1891, as *Ag. granulatus*, dark red form (FH). Hotson, New Richmond Beach, Washington, Oct. 8, 1933 (UW). University of Toronto Herbarium, 9617, coll. H. S. Jackson, York County, Ontario, Canada, Oct. 4, 1936 (UT). Hesler, 14076, New Hopewell, Knox County, Tennessee, Nov. 26, 1941 (UT); 14117, Ball Camp Pike, Knox County, Tennessee, Dec. 19, 1941 (UT); 14354, Highlands, North Carolina, Sept. 3, 1942 (UM, UT); 15910, Claxton School, Anderson County, Tennessee, Oct. 17, 1943 (UT). Mains, 32-532, Au Train, Michigan, Sept. 3, 1932 (UM); 32–776, Harbor Springs, Michigan, Sept. 14, 1932 (UM); no number, Presque Isle County, Michigan, Sept. 13, 1935 (UM). Kauffman, Ithaca, New York, Aug. 9, 1902 (UM); Ann Arbor, Michigan, Aug. 27, 1905, as *L. granulosa* (UM); Marquette, Michigan, Aug. 27, 1906 (UM); Whitmore Lake, Michigan, Oct. 4, 1907 (UM); North Elba, New York, Sept. 10, 1914 (UM); Wassott, Wisconsin, Aug. 23, 1921, coll. L. Dosdall (UM); Mt. Hood, Oregon, Oct. 13, 1922 (UM); Lake Quinault, Washington, Sept. 14, 1925 (UM). Kelly, 983, as *L. amianthina*, det. Beardslee, Magnetawan, Ontario, Canada, Aug. 29, 1921 (UM); Magnetawan, Ontario, Aug. 23, 1924, as

L. adnatifolia, det. Kelly (UM). Walters, Cleveland, Ohio, Oct. 20, 1942 (UM). Zeller, 9172, Big Creek, Lincoln County, Oregon, Nov. 19, 1934 (UM, Z); same locality, Nov. 7, 1935 (UM, Z); 9304, 9305, Florence, Oregon, Nov. 23, 1935 (UM, Z).

The following collections are deposited in the Mycological Herbarium of the Department of Agriculture, Ottawa, Canada. F–5704, Mt. Burnet, Quebec, Sept. 30, 1934; F–6979, same locality, Sept. 13, 1936; F–7565, Eardly, Quebec, Sept. 22, 1937; F–7619, Chalk River, Ontario, Sept. 3, 1937; F–7874, Mt. Burnet, Quebec, Oct. 17, 1937; F–9592, Petawawa Forest Experiment Station; F–9627, Ingolf, Ontario, Aug. 21, 1939; 11128, Petawawa Forest Experiment Station, Sept. 29, 1942.

Observations. — This species varies considerably in color from cinnabar red to reddish orange, with the result that it is likely to be confused with *C. granulosum* var. *adnatifolium* if one does not check for the presence of the cheilocystidia. The cystidia are irregular in their distribution, and at times both pleurocystidia and cheilocystidia are abundant, though usually only the cheilocystidia can be readily demonstrated. The relationship of *C. granulosum* var. *typicum* f. *robustum*, *C. granulosum* var. *adnatifolium*, and *C. cinnabarinum* needs further study. We have selected the most practical differences found, namely, the presence of cystidia, as the basis for recognizing *C. cinnabarinum* and *C. australe*. There are several color forms of *C. cinnabarinum* which should perhaps be given recognition. Since Konrad and Maublanc and Bresadola did not describe cystidia for the fungus they illustrated as *C. cinnabarinum* and since their plates do not show the brilliant colors typical of that species as we know it, we believe that their plates are properly referred to *C. granulosum* f. *robustum*.

5. **Cystoderma australe,** sp. nov.

Pileo circa 15 mm. lato, subplano, sicco, persistenter verruculoso- vel squarruloso-squamuloso, uniformiter ferrugineo-fusco, specimina obscuriora *Cystodermatis granulosi* in mentem revocante; carne tenui, pallida, odore saporeque haud notatis; lamellis confertis, latis, albis vel albidis ac paulum decolorantibus in siccitate, aciebus integris; stipite circa 20×2 mm., curvato, pileo concolori vel vix fortius vinaceo-tincto, ad apicem sericeo, deorsum fibrilloso-squamuloso, annulo distincto destituto, zona velo rupto

relicta in medio stipitis vel infra. Sporis 4–5.5 (6.5) × 2.7–3.4 μ, anguste ellipsoideis, levibus, haud amyloideis, vel multis sporis conglomeratis vix pseudoamyloideis; basidiis tetrasporis, 16–22 × 5–6 μ; pleurocystidiis interdum praesentibus prope aciem lamellarum et tunc cheilocystidiis similibus; cheilocystidiis abundantibus, forma sua ea *Cystodermatis cinnabarini* in mentem revocantibus, 12–21 × 4–5.5 μ, parte angustata 1.5–4 μ crassa; textura tramali lamellarum regulari, hyphis subintertextis, in KOH hyalinis; cuticula pilei ex hyphis ovoideis vel ellipsoideis vel elongatis vel subirregularibus, subcatenulatis consistente, membranis hypharum harum levibus, subincrassatis, KOH ope luride ferruginascentibus; carne pilei ita ut hyphis subcuticularibus in medio alcalino (KOH) hyalinis, laxis, septis fibuligeris. Habitatio: ad ligna putrescentia arborum frondosarum Floridae meridionalis.

Pileus about 15 mm. broad, nearly plane with a wavy elevated margin, surface dry and covered with small wartlike or pointed persistent scales, evenly dark rusty brown over all ("Verona brown" when dried), the colors similar to those of dark specimens of *C. granulosum* and both assuming the same color in drying; flesh thin, pallid, odor and taste not recorded; lamellae close, broad, adnate, white or whitish and only slightly discolored in drying, edges even; stipe about 20 mm. long, 2 mm. thick, curved, tinged with the color of the pileus or slightly more vinaceous, silky above, lower portion fibrillose-scaly with small scales similar in color to those of the pileus, no distinct annulus present, the zone left by the broken veil median or slightly lower.

Spores 4–5.5 (6.5) × 2.7–3.4 μ, narrowly ellipsoid, smooth, nonamyloid or in mass slightly pseudoamyloid; basidia four-spored, hyaline in KOH, subcylindric to narrowly clavate, 16–22 × 5–6 μ; pleurocystidia if present near the gill edge and similar to cheilocystidia; cheilocystidia abundant, similar in shape to those of *C. cinnabarinum*, 16–22 × 4–6 μ, the narrowed portion 1.5–4 μ thick; gill trama regular, the hyphae slightly interwoven, hyaline when revived in KOH; cuticle of pileus of ovoid to ellipsoid or elongated to somewhat irregularly shaped cells loosely arranged in chains, sphaerocysts not numerous, the walls smooth, slightly thickened and dull rusty brown in KOH; flesh of pileus including subcuticular hyphae hyaline or nearly so in KOH, hyphae loosely arranged, clamp connections abundant.

Habitat. — Solitary on a decayed log on the ground.

Distribution. — Known only from the type collection, Singer, F–1184, Matheson Hammock, Dade County, south Florida, Oct. 22, 1942 (FH).

Observations. — Although this species has the same type of cheilocystidia as *C. cinnabarinum*, it is readily distinguished by its habitat on decaying nonconiferous logs, its southern distribution, the color of the pileus, and the stature of the carpophore. This combination of characters cannot be disregarded. From *C. granulosum*, in which it was placed at the time of its collection, it can readily be distinguished not only by its characteristic cheilocystidia but also by the difference in the coloring of the subcuticular hyphae in KOH. In *C. australe* the reaction is not much stronger than that found in *C. amianthinum* var. *typicum;* in other words, it is almost lacking.

6. Cystoderma rhombosporum (Atkinson), comb. nov.

Lepiota rhombospora Atkinson, Proc. Am. Phil. Soc., 57 : 356. 1918.
Armillaria rhombospora Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 4 (1924) : 317. 1925.

Illustrations: Figures 4, 7, spores and cheilocystidia (p. 84).

"Gregaria vel solitaria, 3–4 cm. alta: pileo convexo, 8–15 mm. lato, 1 cm. alto, adolescente ochraceo-fulvo, demum ochroleuco granuloso et squamuloso: squamulis cellis rotundatis vel obovatis vel pyriformibus praeditis: lamellis stipite adnatis vel adnexis, sinuatis, ventricosis, argillaceis: cystidiis solum in acie lamellarum, lanceoideis, 24–32 × 6–8 μ; sporis quaternis, bilateralibus, albis, a fronte rhomboideis et utrimque acutiusculis, a latere inequilateralibus, levibus, 4–5 × 3–4 μ: stipite aequali, pileo concolore, granuloso et squamuloso.

"Nos. 24323 and 24324, type. C. U. Herb."

The original description has been quoted. The following microscopic data were obtained from Atkinson's collection, 24324: Spores 5–6 × 3.8–4.5 μ, subrhomboid to ventricose-apiculate, smooth, nonamyloid, hyaline in KOH when isolated, very faintly though distinctly tinged cinnamon when seen in groups on the faces of the gills; basidia 16–18 × 5–6 μ, four-spored, hyaline in KOH, pale yellow in iodine; pleurocystidia not seen; cheilocystidia abundant, 26–38 × 5–7 μ, narrowly fusoid-ventricose or some subcylindric with an abruptly narrowed elongated flexuous apical proliferation, hyaline

in KOH, yellow in iodine, thin-walled (when groups are viewed in KOH the bases of some appear pale cinnamon, but this was not evident on isolated cystidia); gill trama regular, of parallel long narrow hyaline hyphae, subhymenium very thin and not distinctive, pale yellow in iodine; pileus trama with a cuticle of ellipsoid to globose cells 12–30 × 10–18 μ, arranged in chains, the cells readily separating from one another, some clavate cells borne on narrow pedicels also present in the layer and occasional scattered filamentous hyphae also present, when revived in KOH the cuticular cells smooth, tawny to pale tawny, and with minute pores extending through the wall; subcuticular hyphae filamentous and hyaline or only faintly yellowish in KOH; flesh proper hyaline or tinged pale cinnamon in KOH, of compactly interwoven hyphae, clamp connections present.

Habitat. — Solitary to gregarious in the edge of mixed woods on leaf mold. By Stewart's Camp, Seventh Lake, Adirondack Mountains, New York. August.

Distribution. — The distribution of this rare species remains to be established. At present it is known only from the type locality.

Material studied. — Atkinson, 24324 (CU).

Observations. — This species is readily distinguished from all other members of the genus by the shape of its spores. They resemble those of some species of Tubaria. Since the deposit was described as white, we are not inclined to place much emphasis at present on the very slight coloration observed in the spores adhering to the hymenium, but when the species is re-collected, efforts to get good spore deposits on white paper should be made in order to check the possibility of a creamy or slightly more yellowish tint being present. It is possible that *C. rhombosporum* is a connecting link with the genus Naucoria. We have retained it here in Cystoderma because the spore wall is very thin and typical for the genus, and its color is by no means so distinct as it is in even the pale-spored Naucoriae. In addition, the cuticular cells of the pileus do not have an incrusting pigment.

SECTION II: AMIANTHINA A. H. Smith and R. Singer, Sec. Nov.

Sporis amyloideis.

7. *Cystoderma carcharias* (Pers. ex Secr.) Fayod, Ann. Sci. Nat., Sér. 7, 9:351. 1889.

Agaricus granulosus d Fries, Syst. Mycol., 1:25. 1821.
Agaricus carcharias Pers. ex Secretan, Mycogr. Suisse, 1:62. 1833.
Agaricus granulosus var. *carcharias* Fries, Epicr. Syst. Mycol., p. 18. 1836.
Agaricus granulosus subsp. *incarnato-albida* Fries, Monogr. Hymen. Suec., 1:29 (13 in reprint). 1857.
Lepiota granulosa var. *carcharias* Gillet, Les Hyménomycètes, p. 71. 1874.
Lepiota carcharias Karsten, Hattsvampar, p. 14. 1879.
Armillaria carcharias Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 4 (1924):317. 1925.

Illustrations:
Fig. 9, spores (p. 84).
Barla, Champ. Alp. Mar., pl. 15, figs. 16–18.
Bigeard et Guillemin, Champ. Suppl. Fr., p. 53, pl. 11, fig. 5.
Boudier, Icon. Mycol., Vol. I, pl. 14.
Bresadola, Icon. Mycol., Vol. I, pl. 38.
Briganti, De fungis rarioribus regni neapolitani historia, pl. 17, figs. 4–7.
Britzelmayr, Hymen., pl. 34, fig. 135 (*L. carcharias* f. *isabellina*, pl. 158, fig. 744).
Cooke, Illus. Brit. Fungi, no. 37, pl. 42.
Krombholz, Naturgetreue Abbildungen und Beschreibungen der essbaren, schädlichen und verdächtigen Schwämme, pl. 25, figs. 21–25.
Lange, Flora Agar. Danica, Vol. I, pl. 15, fig. D.
Lucand, Figures peintes des Champignons supérieures de la France, pl. 202.
Persoon, Icon. Fung., pl. 5, figs. 1–3.
Ricken, Die Blätterpilze, Vol. II, pl. 82, fig. 3.
Voglino, Nuovo giorn. bot. ital., 19 (1887), pl. 7, fig. 8.

F. *typicum*

Pileus 2.4–4 cm. broad, obtuse to convex when young, expanding to plane or often remaining umbonate, surface dry and covered with very minute to medium-sized granules, pale lilaceous to pallid flesh color, pale sordid tan when dried, the margin often denticulate from the remains of the broken veil; flesh whitish to ochraceous, odor unpleasant, mawkish, taste disagreeable; lamellae adnate to slightly adnexed, white or pallid whitish, moderately broad, close; stipe 3–6 cm. long, 4–8 mm. thick, subbulbous and gradually narrowed upward, apex white to pallid but in age becoming sordid brownish flesh color, granulose and more or less concolorous with the pileus

below the superior annulus, in age also becoming sordid brownish flesh color; annulus well developed and flaring at first, granulose on under side, eventually collapsing and sometimes evanescent; surface of pileus olive yellowish to dirty alutaceous in KOH.

Spores white in deposits, (3.6) 4.5–5.5 × 3.2–3.9 μ, distinctly but moderately strongly amyloid, ellipsoid, with a hilar applanation, not depressed, hyaline, smooth; basidia 16–28 × 5–6.4 μ, four-spored; pleurocystidia and cheilocystidia not differentiated; gill trama hyaline and regular; pileus trama with a cuticle of enlarged to more or less globose cells readily becoming detached from one another, the cells 11.5–35 × 11–22 μ, hyaline in KOH; subcuticular layer also hyaline in KOH, all hyphae with clamp connections.

Habitat. — Scattered to gregarious under pines and spruce, among mosses or fallen needles or on soil, July to November. Rare in North America; not uncommon in Europe.

Distribution. — Europe and possibly North America. In Europe it is known from all the larger countries, and its pattern of distribution covers the entire continent. In the United States it appears to be very rare and is doubtfully known from New York and Idaho.

Material studied. — Fresh material was studied by Singer from various places in Czechoslovakia, Austria, and Germany, 1923–31, and from Peterhof, Leningrad region, U.S.S.R., 1937 (L). The following collections of dried specimens have been examined: Hoehnel, two collections from Tullnerbach, Wienerwald, Austria (FH, in Hoehnel Herb.); Bresadola, Italy (FH). France, Patouillard Herb., ex Herb. Sarazin (FH), as *L. granulosa* var. *carcharias*, Nov., 1886; Germany, Allescher and Schnabl, Fungi Bavarici, 235. United States, Kauffman, Seventh Lake, Adirondack Mts., New York, Sept. 1, 1921, as *L. rugosoreticulata*, the identification doubtful.

Observations. — Two fruiting bodies which appeared to belong in this species were found near the Lake Fork Ranger Station, Idaho National Forest, Idaho, but were unfortunately lost in drying, so that the microscopic details could not be rechecked from the dried specimens. Actually the occurrence of f. *typicum* in North America is not too well established. Singer, who has studied the Kauffman material, expressed doubt as to its identity but at the same time admitted that no other disposition was as satisfactory. No record was made of the KOH reaction of the cuticle on the Idaho collection before it was lost.

F. album (Fr.), comb. nov.

Agaricus carcharias var. *B* Secretan, Mycogr. Suisse, I: 62. 1833.
Agaricus carcharias var. *alba* Fries, Hymen. Eur., p. 36. 1874.
Lepiota carcharias var. *alba* Saccardo, Syll. Fung., 5: 46. 1887.
Illustrations:
Plate II.
Harzer, Naturgetreue Abbildungen der Pilze, pl. xliv, fig. B (as *Ag. cristatus*).

Pileus 1–3.5 cm. broad, convex or with a slight umbo, sometimes obtusely conic, surface dry and densely covered with small granulose warts or scales or with a more or less even powdery covering when the scales have been worn or broken down, surface even or slightly radially rugose, color white to whitish, becoming "cartridge buff" at times, margin noticeably appendiculate with submembranous patches of the broken veil, the outer side of the patches bearing small powdery scales similar to those on the pileus; flesh white, thick on the disc, thin toward the margin, firm, dry; lamellae close, 35–39 reach the stipe, broad (3 mm.), broadly adnate, slightly but sharply adnexed, white, edges crenulate; stipe 5–7 cm. long, 2.5–3 mm. thick, equal above a base enlarged by adhering white mycelium and débris, increasingly granulose-scaly up to the apical submembranous annulus, white and silky above, glabrescent and merely faintly powdery in age, stuffed, concolorous with the pileus at all stages; annulus with powdery scales on under side, upper surface silky.

Spores 4–5 × 3 μ, hyaline, ellipsoid, smooth, amyloid; basidia four-spored, 20–24 × 4–5 μ; pleurocystidia and cheilocystidia not differentiated; gill trama homogeneous, its hyphae parallel to subparallel, hyaline in KOH, yellow in iodine; pileus trama homogeneous beneath a surface layer of globose thin-walled hyaline cells 20–35 μ in diameter, hyaline in KOH, yellowish in iodine, clamp connections present on the filamentous hyphae of pileus and gill trama.

Habitat. — Gregarious under conifers. Late summer and fall. Rare.

Distribution. — Europe and North America.

Material studied. — Smith, 11091, from under Norway pine (*Pinus resinosa* Ait.), Ogemaw State Forest, Midland, Michigan, Sept. 25, 1938 (FH, UM).

Observations. — This collection was originally referred to *A. Ambrosii* Bresadola (see Smith, 1942), but the occurrence of a very similar fungus in Oregon having nonamyloid spores and more lacerate

than granular scales on the stipe throws doubt on the identification. Since it is now impossible to obtain data on Bresadola's type, the greatest emphasis is here placed on the more laccrate scales of the stipe in the Oregon collection, and since this character is in line with Bresadola's description, the western collection is here identified as *C. Ambrosii*. The Ogemaw Forest collection differs from pale forms of *C. amianthinum* in the reaction of the cells of the cuticle in KOH.

8. Cystoderma pulveraceum (Peck), comb. nov.

Lepiota pulveracea Peck, Ann. Rep. New York State Mus., 54: 144. 1901.
Armillaria pulveracea Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 4 (1924): 317. 1925.

Pileus 1–2.5 cm. broad, hemispheric becoming convex or nearly plane, dry, pulverulent or minutely granulose and squamulose, even on the margin, whitish or pallid inclining to tawny ("pinkish buff" to "Sayal brown" in herbarium specimens); lamellae thin, close, adnexed, yellowish white; stipe 2.5–5 cm. long, 3–4 mm. thick, equal to slightly clavate, hollow, white and pruinose at the apex, granulose or squamulose below the obsolete annulus and there colored like the pileus.

Spores 4–4.5 × 2.2-2.4 μ, ellipsoid, amyloid, smooth, hyaline in KOH; basidia four-spored, 14–16 × 3–4 μ, hyaline in KOH, yellow in iodine (the hymenium often pale to bright rusty yellow brown in iodine); gill trama parallel to subparallel, hyaline in KOH, yellow in iodine, subhymenium very thin and indistinct; pileus trama of hyaline filamentous hyphae (in KOH), compactly interwoven, clamp connections present; cuticle of pileus made up of globose to ellipsoid cells borne in chains which soon break up into the component cells, the latter 10-18 (22) μ in diameter, or if ellipsoid up to 40 μ long, some cylindric cells present (more than in *C. amianthinum*), many cells furnished with a flexuous proliferation from the apex, the walls thin and hyaline when revived in KOH or only very faintly yellowish, the subcuticular layer well developed and of hyaline much-branched hyphae 6–8 μ in diameter.

Habitat. — Single to scattered on old conifer logs. August and September. Rare.

Distribution. — New York and Michigan. Known only in North America.

Material studied. — Peck, Floodwood, August (NYS); Kauffman,

Marquette, Michigan, Sept. 2, 1906, on a rotten hemlock log, ex Herb. Kauffman, 507 (UM); North Elba, New York, Sept. 4, 1914 (UM).

Observations. — The microscopic data were obtained from Kauffman's North Elba collection. *C. pulveraceum* is most closely related to *C. subvinaceum* and *C. caucasicum.* It is readily distinguished from the former by its paler colors in the fresh condition and by the KOH reaction in herbarium material. From the latter it can be differentiated by the negative reaction with alkaline solutions of the cuticle of the pileus. The habitat and poorly formed annulus distinguish it from the white form of *C. carcharias.*

9. Cystoderma caucasicum Singer, sp. nov.

Pileo 10–13 mm. lato, convexo, demum margine plano, disco saepe subumbonato, albido, squamulis punctiformibus discum versus densioribus et obscurioribus tecto; carne alba; lamellis adnexis vel adnatis, confertissimis vel confertis, latissimis (2–3 mm.) in tertia parte marginali, ventricosis, brunnescentibus, atro-fuscis ad aciem in siccitate; stipite brevi, 12–14 × 2–3 mm., solido, subaequali vel basin versus attenuato, albido, infra annulum appressum, exiguum, persuperum fusco-squarruloso, supra annulum subcaesio-sordido; sporis 4 × 2.5 μ, ellipsoideis, fortiter amyloideis; basidiis 20–25 × 4–4.5 μ, tetrasporis; cystidiis nullis; textura tramali lamellarum subirregulari; hyphis carnis hyalinis; cellulis epithelii brunneolis vel hyalinis in medio ammoniacali; hyphis epithelii stipitis frequentius catenulatis quam in pileo. Habitatio: ad ligna putrida *Abietis Nordmannianae* in silvis mixtis montium Caucasi Occidentalis.

Pileus 10–13 mm. broad, convex, the margin finally spreading and horizontal, in age frequently becoming lobed, disc often remaining slightly and obtusely umbonate, whitish, the punctiform granular scales becoming more crowded toward the disc, darker than the ground color when the caps are dried; flesh whitish; lamellae adnexed to adnate, crowded to close, broadest (2–3 mm.) toward the margin of the pileus and ventricose, brownish when dried, deep bay at the edges in herbarium material; stipe short, 12–14 mm. long, 2–3 mm. thick, solid, subequal or tapering downward, whitish with brown erect scales, which leave the apex uncovered and naked and form a whitish appressed small annulus just below the apex, somewhat caesious-sordid at apex.

Spores 4 × 2.5 μ, hyaline, thin-walled, entirely regularly ellipsoid, strongly amyloid, smooth; basidia 20–25 × 4–4.5 μ, four-spored; pleurocystidia and cheilocystidia none; subhymenium subcellular, consisting of small cells of about 3.5 μ in diameter; trama of gills rather irregular, consisting of hyphae 9 ± μ in diameter, which are frequently short-celled; flesh of pileus consistently of subparallel but variable cells up to 14 μ in diameter and hyaline (NH_4OH); epithelium formed of short-ellipsoid to globose vesiculose cells, some with brownish content and some remaining colorless in NH_4OH, the walls moderately thickened (0.8 μ); the epithelium of the stipe similar but the cells more often connected in chains.

Habitat. — On decayed wood of *Abies Nordmanniana* Spach in mixed woods of beech and fir; elevation 700 meters.

Distribution. — Known only from the type locality near Guseripl, West Caucasus, Caucasus Mts., U.S.S.R.

Material studied. — The type (L).

Observations. — This material was first identified and published as *C. echinella* (Quél.) Singer apud Vasilieva, *Uchenye zapiski Kazansk. Universiteta,* 105 (99) : 56. 1939. Quélet's species, however, is described as having free gills, as growing on the ground, and with spores 6–7 × 3–3.5 μ. Further consideration of these characters in the light of the information brought together here on Cystoderma indicates that the fungus in question is a previously undescribed species. It appears to be most closely related to *C. pulveraceum,* but is readily distinguished by the dissolved brownish pigment in at least some of the cells of the epithelium.

10. *Cystoderma amianthinum* (Scop. ex Fr.) Fayod, Ann. Sci. Nat., Sér. 7, 9 : 351. 1889.

Agaricus granulosus subsp. *amianthinus* Fries, Epicr. Syst. Mycol., p. 18. 1836.
Agaricus granulosus subsp. *subochracea* Fries, Monogr. Hymen. Suec., 1 : 29 (13 in reprint). 1857.
Agaricus amianthinus Scop. ex Fries, Hymen. Eur., p. 37. 1874.
Lepiota granulosa var. *ochracea* Gillet, Les Hyménomycètes, p. 71. 1874.
Lepiota amianthina Karsten, Hattsvampar, p. 15. 1879.
Armillaria amianthina Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 2 (1922) : 60. 1923.
? *Armillaria muscicola* Cleland, Trans. and Proc. Roy. Soc. South Australia, 51 : 299. 1927.

Illustrations:
Figure 11, spores (p. 84).
Barla, Champ. Alp. Mar., pl. 16, figs. 9–11.

Batsch, Elench. Fung., fig. 97 (as *Ag. flavo-floccosus*).
Bolton, History of Funguses Growing about Halifax, pl. 51, fig. 2 (as *Ag. croceus*).
Boudier, Icon. Mycol., Vol. I, pl. 16.
Bresadola, Icon. Mycol., Vol. I, pl. 37.
Britzelmayr, Hymen., pl. 42, fig. 295.
Bulliard, Herbier de la France (Histoire des Champignons de la France), Vol. III, pl. 362; Vol. IV, pl. 530, fig. 3 (as *Ag. ochraceus*).
? Cleland, Toadstools and Mushrooms of South Australia, Part I, fig. 10 (as *A. muscicola*).
Cooke, Illus. Brit. Fungi, no. 40, pl. 213, lower figures (very poor and possibly applying to a true Lepiota).
Doassans et Patouillard, Les Champignons figurés et desséchés, no. 18.
Farlow and Burt, Icones Farlowianae, pl. 10, lower figures (as *L. granulosa*).
Flora Danica, Fasc. 17 (1790), tab. 1015, fig. 2 (as *Ag. muricatus*).
Greville, Cryptog. Flora, 2, pl. 104 (as *Ag. granulosus*).
Harzer, Naturgetreue Abbildungen der Pilze, pl. 4, fig. 2.
Hoffmann, Icon. Anal. Fung., pl. 13, fig. 1 (as *Ag. granulosus*).
Hotson, Mycologia, 32: 785. 1940, fig. 1.
Hussey, Illus. Brit. Mycol., Vol. I, pl. 45.
Krombholz, Naturgetreue Abbildungen und Beschreibungen der essbaren, schädlichen und verdächtigen Schwämme, pl. 1, fig. 12 (as *Ag. granulosus*).
Lange, Flora Agar. Danica, pl. 15, fig. C.
Lanzi, Fungi di Roma, pl. 110, fig. 1.
Murrill, Mycologia, Vol. VII, pl. 158, fig. 5.
Patouillard, Tab. Anal. Fung., fig. 610.
Ricken, Die Blätterpilze, Vol. II, pl. 81, fig. 4.
Sicard, Hist. Nat. Champ., pl. 18, fig. 24.
Sowerby, Colored Figures of English Fungi or Mushrooms, pl. 19 (as *Ag. croceus*).

(*a*) Var. *typicum* f. *typicum*

Pileus (1.5) 2–3.5 (4.5) cm. broad, obtuse to convex, expanding to broadly convex or at times remaining obtuse, sometimes obtusely umbonate, the margin at first beautifully appendiculate with the more or less triangular flaps of tissue left by the broken veil, surface even to somewhat radially rugulose, dry and granulose, the granules aggregated into small spotlike scales which are more crowded on the disc, when young usually "buckthorn brown" (dull to rather bright ochraceous brown) on the disc and "antimony yellow" (pale yellow) toward the margin, finally "tawny" to "ochraceous tawny" or "yellow ocher" to almost "raw sienna" over the disc and paler (between "chamois" and "honey yellow") toward the margin, becoming deep fulvous ferruginous with ammonia or KOH; flesh white or whitish, thin except in the disc, odor disagreeable, mawkish or not distinctive, taste mild; lamellae moderately close to crowded, about 2 tiers of lamellulae, moderately broad (2.5–3.5 mm.), squarely adnate at

first but often developing a tooth and becoming somewhat sinuate, white or whitish but usually pale orange yellow at maturity (sometimes "warm buff"), edges even; stipe 2.5–6 cm. long, 2–7 mm. thick at apex, equal or very slightly enlarged downward, solid, often becoming hollow, pith pallid, usually becoming brownish in age in the lower portion, surface sheathed with a granulose sheath up to the median to superior evanescent annulus, granulose portion concolorous with the pileus, pallid to yellowish and pruinose above the annulus, base with adhering white mycelium; annulus usually poorly formed and evanescent, tawny and granulose on outer or under side, and pallid and silky on upper or inner side if well formed.

Spores narrowly ellipsoid, hilar depression slight or lacking, (4.2) 4.5–6.5 (7.5) × (2) 2.8–3.5 μ, distinctly though not always strongly amyloid, hyaline in KOH; basidia 21–28 × 5.5–7 μ, clavate, four-spored, hyaline in KOH, yellow in iodine; cheilocystidia absent or when present very rare, 26–34 × 5–7 μ, narrowly ventricose with obtuse apices; pleurocystidia not seen; gill trama regular, parallel or the central portion becoming somewhat interwoven, hyaline in KOH, yellowish in iodine; pileus trama with a cuticle composed of chains of globose to ellipsoid cells 18–48 (60) × 10–24 (40) μ, their walls smooth to very faintly rugulose and rusty cinnamon color when revived in KOH, the chains readily breaking up into the component cells, very few narrowly ellipsoid to subcylindric cells present in the cuticle, tramal body of hyaline nonamyloid loosely interwoven hyphae, the subcuticular filamentous hyphae hyaline to only slightly pigmented, clamp connections present.

Habitat. — Single to densely gregarious among mosses, frequently on beds of Polytrichum, on fallen leaves in mixed woods, or on needle carpets under conifers. It fruits during the late summer and fall. In regions like California it appears during the winter rainy season. Rather common.

Distribution. — It is known from Europe, Asia, and North America, and probably South Australia. We have not examined material from either Japan or South Australia. Imai (1938) reported it from Japan, and Cleland has described under the name *Armillaria muscicola* what appears to be this species from South Australia. In North America it is known from Quebec and Ontario in Canada, and across the United States from Maine to Washington and south to North Carolina in the East and California in the West.

Material studied. — The following collections of fresh material have been studied: Singer, 129a (FH), 129c (FH) from New York; 107 (L), 108 (L), 200 (L), 200a (L), 200b (L), 372 (L), all from the Altai Mts. of Asia. E. B. and E. E. Mains, 32–544 (UM); Smith, 33–984 (UM) from Michigan; 493 (UM) from New York; 3839 (UM) from California. Hesler and Smith, University of Tennessee 11292, North Carolina (UM, UT). Smith, 7816 (UM) from Oregon; 17271 (UM) from Washington. The following collections of dried material have also been examined: Allescher and Schnabl, Fungi Bavarici, 234 (FH). Simon Davis, Massachusetts, 19110 (UM). Ellis and Everhardt, North American Fungi, 2001 (UM), as *Ag.* (*Lepiota*) *granulosus.* Farlow, Shelburne, New Hampshire, Sept., 1891 (FH) as *Ag. granulatus.* Flett, Bremerton, Washington, Feb. 10, 1940 (FH, UM). Groves, Norway Bay, Quebec (UM). Gruber, 13–7, Canyonville, Oregon, Nov. 27, 1942 (UM). H. Hotson, Washington, Oct. 16, Nov. 5, 1939, and Stuntz, Washington, 391, 395, 496 (UW). Hesler, University of Tennessee Herbarium, 8086, 8437, 14773, 15971 (all UT). Hesler, New Hopewell, Nov. 14, 1937 (FH), as *L. granulosa.* Josserand, Oct. 7, 1937, near Lyon, France (FH, UM). Kauffman, Ithaca, New York, Aug. 19, 1904 (UM), as *L. granulosa;* North Elba, New York, Sept. 3, 1914 (UM); Lake Cushman, Olympic Mts., Washington, Oct. 6, 1915 (UM); Elkmont, Tennessee, Sept. 14, 1916 (UM), as *L. adnatifolia;* Lake Quinault, Washington, Oct. 17, 1925 (UM). Mains, 34–17 (UM) and 34–189 (UM), both from near Marquette, Michigan. Parlin, Canton Point, Maine, 15192, 15202 (UM). France, Sarazin Herb. in Patouillard Herb. (FH). Zeller, Lebanon, Oregon, 7800 (UM, Z). The following collections are deposited in the Mycological Herbarium of the Department of Agriculture at Ottawa, Canada: F–5717, Ingolf, Ontario (Manitoba boundary), Lange and Bisby, Sept. 17, 1931; F–8595, Laurentian National Park, Quebec, Aug. 27, 1938; F–8665, Burnet, Quebec, Sept. 25, 1938; 11427, 11557, Petawawa Forest Experiment Station, Ontario, Sept., 1943.

Observations. — Because of the confusion which has existed in regard to the identity of this species nearly all reports in the literature need to be verified by a study of the specimens on which they are based. Obviously we have not been able to do this. However, the species is common and widely distributed throughout temperate and northern regions. The spores are variable in length in the typical

variety, and this may lead to some confusion in the recognition of the other varieties, particularly var. *sublongisporum*. For a discussion of the differences between these two see page 114. According to our experience, *C. amianthinum* is much more frequently collected in the field than *C. granulosum*, with which it has been mostly confused. The somewhat ventricose cheilocystidia appear to be too rare to help much in identifying *C. amianthinum*. In one collection, Hesler, Nov. 14, 1937 (FH), basidium-like bodies were found near the gill edges; they had thick walls and were without sterigmata or were characterized by one, two, three, or four sterigma-like projections. We have had no opportunity to study them on fresh material and cannot be sure whether they do or do not bear spores. They show up best when mounts are revived in the chloral-hydrate solution used to test the iodine reaction of the spores.

(*b*) Var. *typicum* f. **rugosoreticulatum** (Lorinser), comb. nov.

Agaricus rugosoreticulatus Lorinser, Oest. Bot. Zeitschr., 29: 23. 1879.
Lepiota rugosoreticulata Saccardo, Syll. Fung., 9: 10. 1891.
Armillaria rugosoreticulata Zeller, Mycologia, 33: 378. 1933.

Illustration: Plate III.

Pileus (2) 3–5.5 cm. broad, obtusely conic when young, becoming obtusely umbonate to convex or plane, surface dry and granulose, conspicuously radially rugose or reticulate, color evenly dull yellowish brown to ochraceous brown ("buckthorn brown") or brighter, the margin at first strikingly appendiculate with fragments of the veil; flesh thin, whitish, odor disagreeable to lacking, taste not distinctive; lamellae bluntly adnate, close, narrow, white to whitish, edges even; stipe 4–8 (9) cm. long, 3–8 mm. thick, equal to slightly enlarged either way, stuffed with a white pith, granulose and concolorous with pileus up to the evanescent annulus or with zones or patches of granulose tissue if sheath is broken, smooth above the annulus, apex minutely pruinose and whitish; annulus superior, evanescent, concolorous with pileus and granulose on outer (under) side and smooth and pale buff on the upper side, often ragged and poorly formed.

Spores 5–6 (7.5) × 3 ± μ, amyloid, narrowly ellipsoid, smooth, hyaline, white in mass; basidia four-spored, 18–20 × 5–6 μ, hyaline in KOH, yellowish in iodine; cheilocystidia and pleurocystidia not

differentiated; gill trama subregular to interwoven, the cells more or less cylindric in freshly matured carpophores, 18–80 × 6–9 (12) μ, subhymenium not distinctive; pileus trama with a differentiated cuticle of globose to inflated saccate cells 12–40 × 10–30 μ, originating in chains and having smooth tawny-brown walls when revived in KOH, the layer of irregular thickness and very few elongated to cylindric colored cells present, trama beneath the cuticle of hyaline interwoven hyphae, clamp connections present.

Habitat. — Scattered to gregarious on soil, beds of moss, or mats of conifer needles. Its fruiting period coincides with that of f. *typicum*.

Distribution. — It is to be expected throughout the range of f. *typicum*. It is known from both Europe and North America. We have examined North American material from North Carolina, Tennessee, Michigan, California, Oregon, and Washington.

Material studied. — Fresh fruiting bodies from the George Reserve, Pinckney, Michigan, Smith, 7044 (UM); Lake Crescent, Washington, 3082 (FH, UM); California, 8713 (UM); and Tennessee, Hesler and Smith, 9875 (UM) have been studied. The photograph and description were taken from collection 3082. The following collections of dried material have been examined: Gruber, 20–6, Mt. Scott, Portland, Oregon, Dec. 14, 1942. Hotson, Washington, Oct. 16, 1934 (UW). Hesler, 9590, 12296, 12887, 14391, 14363 (all UT). Kauffman, Marquette, Michigan, Aug. 27, 1906, on ground in birch woods, as *L. rugosoreticulata* (UM), and same locality, beech woods, Kauffman, 533 (UM). Pennington, Whitmore Lake, Michigan, Sept. 14, 1907 (UM). Kauffman and Brown, Takilma, Oregon, Nov. 27, 1925 (UM). Stuntz, F–496, Washington (UM, Z), and F–211, Washington (UW).

Observations. — This is a conspicuous form when the wrinkles of the pileus are well developed, but all degrees of variation are common. The fruiting bodies photographed were all from one group. Many of the other species in this genus also show this character to a greater or a less degree.

(*c*) Var. *typicum* f. **olivaceum** Singer, f. nov.

A typo pileo colore primum olivaceo differt.

Similar to f. *typicum* in all respects except that the pileus and sheath of the stipe are olive in color at first, and gradually fade to yellowish.

Habitat. — Same as that of f. *typicum.*

Distribution. — Siberia.

Material studied. — Collections by Singer (L).

Observations. — This form has all the characters of the type form except color, even to becoming yellowish, as in f. *typicum*, when old, and then is indistinguishable from it. Both forms have been collected growing near each other, but f. *olivaceum* always occurred in large homogeneous groups and appears to be a minor mutation from f. *typicum.*

(*d*) Var. *typicum* f. **album** (Maire apud Rea), comb. nov.

Lepiota amianthina var. *alba* Maire apud Rea, Brit. Bas., p. 76. 1922.

"Differs from the type in being entirely white."

Habitat. — Same as that of f. *typicum.*

Distribution. — England and United States.

Material studied. — Parlin, 15485 (FH, UM), Canton Point, Maine, Nov. 16, 1942.

Observations. — The dried specimens of the one collection placed here varied from nearly white to pale yellow. We have not seen fresh material and have recognized the form largely on the strength of Maire's identification. In keeping with our treatment of color variants, it is here treated as a form. The reaction of the cuticle in KOH should readily distinguish this form from f. *album* of *C. carcharias.*

(*e*) Var. **sublongisporum** Singer, var. nov.

Illustration: Figure 10, spores (p. 84).

A typo colore pilei (squamulis rufo-badiis interstitiisque dilute aurantio-flavis) et sporis aliquantulum majoribus et contextu tramali lamellarum KOH ope discolorato et pallido-cinnamomeo-tincto differt. Habitatio: ad humum et ligna putridissima inter muscos et folia delapsa in silvis mixtis et piceinis Americae Borealis.

Pileus 10–35 mm. broad, obtusely umbonate when young, becoming campanulate or expanded-umbonate, sometimes broadly convex, margin at first appendiculate with remnants of the veil, surface dry and covered with small granulose scales, the scales tending to remain distinct in old or dried carpophores, color at first evenly "mahogany red" to "auburn" (deep brownish red) from the highly

colored scales, ground color "light orange yellow" and more conspicuous on disc, causing the surface to appear paler toward the margin, in age or when dried more or less "amber brown" (bright yellowish brown); flesh thin, tinged rufous or in age pallid, odor none, taste not distinctive; lamellae bluntly adnate becoming sinuate-adnate at maturity, close to crowded, moderately broad, pale yellowish ("warm buff" to "pale orange yellow"), edges even; stipe 30–60 mm. long, 3–6 mm. thick at apex, tapered upward to nearly equal, lower portion sheathed by granular-tomentose veil remnants that are concolorous with the scales of the pileus, sheath terminating a more or less evanescent fibrillose median zone, white pruinose above but soon yellowish and when dried pale tawny, the sheath drying slightly darker.

Spores (5.3) 6.2–7.5 (8) × 2.8–3.8 μ, smooth, narrowly ellipsoid, amyloid; basidia four-spored, 22–24 × 5.5–7 μ, hyaline in KOH, yellow in iodine, narrowly clavate; pleurocystidia and cheilocystidia not differentiated or very rare, when present basidium-like but with one obtuse sterigma-like apical prolongation; gill trama homogeneous, subparallel, hyaline in KOH near the gill edge but in many sections tinged cinnamon toward the junction with the trama of the pileus, yellow in iodine; pileus trama moderately dark to pale ferruginous cinnamon near the cuticle and paler toward the subhymenium when revived in KOH, the hyphae compactly interwoven, clamp connections present; cuticle of pileus and subcuticular hyphae deep ferruginous when revived in KOH (almost blackish when KOH is applied directly to cap surface), the cells globose to ellipsoid and in chains, the latter readily breaking up into single cells, a fairly large number of subcylindric to clavate-pedicellate cells often present in addition, the globose and ellipsoid cells 14–32 (40) μ in the longest dimension, the pedicellate cells at times up to 60 μ long.

Habitat. — Solitary to gregarious on rich humus, very rotten logs, among mosses and fallen leaves in mixed forests or on needle carpets under spruce. It usually fruits during the late summer and fall, but Hesler has one collection from under red spruce made in June at an altitude of 5,200 feet.

Distribution. — It is known across the North American continent from New York, Ontario, and Washington. It has also been found in Tennessee in the Great Smoky Mountains National Park. Collections from Maine and Oregon, which appear to belong here but

which are not typical in coloration, have also been examined. The variety probably occurs throughout the range of var. *typicum* in North America, but is not so common.

Material studied. — Fresh carpophores from the Huntington Wild Life Forest, Newcomb, New York, Sept., 1941, Singer, 97 (FH), have been studied and are designated as the type. Other collections are as follows: Smith, 16881, Ermine Creek Trail, Baker National Forest, Washington (UM). Roy F. Cain, Bear Island, Lake Timagami, Ontario, Sept., 1936 (UM). The following collections of dried material have also been examined: Hesler, 10433 (UM, UT), 10915, 13928, 13988 (all UT). Hesler and Smith, 9764 (UM). Kauffman, Lake Quinault, Washington, Oct. 31, 1925 (UM); Kauffman, same locality, Nov. 5, 1925 (UM). Parlin, Canton Point, Maine, 15476 (UM), with carpophores paler than usual. Other atypical collections are as follows: Smith, 4656, Sand Point, Lake Timagami, Ontario (UM). Zeller, 9179, Oregon (UM, Z).

Observations. — The colors of both fresh and dried carpophores are quite distinctive and nearly always serve as an accurate characteristic between var. *sublongisporum* and var. *typicum*. Somewhat bleached or faded fruiting bodies are sometimes found as indicated in the material cited, but when these are sectioned and mounted in KOH the pallid-cinnamon gill trama and darker pileus trama were found to be constant. No white forms with these characters have been met with. In dried specimens the gills of var. *sublongisporum* are consistently darker orange buff than in var. *typicum*. The spore size is somewhat variable. In Smith, 16881, the spores were not more than 6.3 μ long. In most collections this is near the lower limit of the range. The granulose scales on the pileus are typically coarser and more persistent than in var. *typicum*. In the character of the veil as well as in color var. *sublongisporum* approaches *C. fallax* but can be distinguished at once by the sharp difference in both the size and the shape of the spores. In addition, the annulus is never so well formed and persistent.

(*f*) Var. **longisporum** (Kühner), comb. nov.

Lepiota amianthina var. *longispora* Kühner, Bull. Soc. Mycol. Fr., 52: 204. 1936.
? *Agaricus Jasonis* Cooke and Massee, Grevillea, 16: 77. 1887.
? *Armillaria Jasonis* Saccardo, Syll. Fung., 9: 12. 1891.

Illustration: (?) Cooke, Illus. Brit. Fungi, 1113, pl. 955.

Pileus 2.5 cm. broad, campanulate, hemispheric or convex, rhubarb yellow, granulose, then tessellate-roughened from distinct pyramidal floccules which are concolorous, or which break off leaving a brownish-red patch on a background of golden ocher; flesh with a distinct horn-colored line, the odor weak and not earthy; 32 lamellae reach the stipe, 3–5 tiers of lamellulae, yellowish white, becoming subhorizontal, adnate or slightly sinuate; stipe 2.5 cm. long, 3 mm. thick, equal, with an ocher-brown floccose-woolly covering, the apex naked or with soft fibrils and yellowish gray brown, stuffed with a pith, flesh brownish in the base, yellowish above, finally entirely brown; cortina arachnoid-woolly but not forming a membranous annulus as in *C.* (*Lepiota*) *carcharias*.

Spores distinctly elongated, 7–9 × 4–4.7 μ, ellipsoid, or often somewhat ventricose-fusoid, faintly amyloid; basidia four-spored, 21–22 × 6.5–7 μ; hyphae with clamp connections.

Habitat. — On decaying stumps in woods of Picea. August.

Distribution. — France (Alps) and also England, if the synonymy is accepted.

Material studied. — None. The account is taken from Kühner's original description.

Observations. — As we have indicated above, we suspect that *Agaricus Jasonis* Cooke and Massee is the same as Kühner's variety. The flesh of *Ag. Jasonis* is described as reddish, but as illustrated by Cooke it is merely ochraceous buff and, consequently, it does not appear advisable to place much emphasis on this difference until it can be checked from fresh material. A difference in size of the carpophores should not be assumed simply on the basis of the two descriptions, since it is evident that not much is known of the variation of this fungus. Neither can the strong odor as described for *Ag. Jasonis* be given much emphasis taxonomically. Kühner reported the odor as weak, but obviously one was present in his specimens. In f. *rugosoreticulatum* the odor varies greatly, and its presence is not correlated with the wrinkles of the pileus. The iodine reaction of the spores of *Ag. Jasonis* must be ascertained before the species can be assigned to any other position in our classification. Although we do not record this variety as occurring in North America, we have seen one fruiting body, collected by L. K. Henry of Pittsburgh, Pennsylvania, which would key out here by virtue of its large spores. Since no information on the macroscopic characters of the fresh

fruiting body is available and since there are some slight discrepancies in the microscopic characters, we have been unable to arrive at a definite conclusion in regard to its proper place in our classification.

KEY TO VARIETIES AND FORMS OF *C. AMIANTHINUM*

I. Spores 4.5–6.5 (7.5) μ long. Gill trama hyaline in KOH .... var. *typicum*
  A. Pileus conspicuously rugose-reticulate ..... f. *rugosoreticulatum*
  B. Pileus not as above; often slightly wrinkled
    1. Pileus yellow to tawny at first ..... f. *typicum*
    2. Pileus olive when young ..... f. *olivaceum*
    3. Pileus white or whitish ..... f. *album*
II. Spores regularly 6.2–8 or more μ long. If spore size intergrades, then gill trama pale cinnamon in KOH, at least on some of the sections
  A. Spores regularly 2.8–3.8 μ broad; gill trama pale cinnamon in KOH var. *sublongisporum*
  B. Spores 4–4.7 μ broad and 7–9 μ long ..... var. *longisporum*

11. Cystoderma fallax, sp. nov.

Illustrations: Plate IV; Text Figure 8, spores (p. 84).

Pileo 2–5 cm. lato, interdum abrupte umbonato, margine primum vel fragmentis membranaceis ornato, superficie initio squarrulosogranulosa, demum pulveracea, vel squamis circa discum persistentibus, fulvo-ferrugineis instructa; carne albida vel superficiei subconcolori; lamellis adnatis vel rotundato-adnexis, confertis, intermixtis, angustis, carneo-alutaceis, integris; stipite 30–60 (80) × 3–7 mm., plerumque incrassato basin versus vel deorsum clavato, subinde subaequali, solido, intus pallido vel flavidulo, cothurnato ad annulum distantem, membranaceum tegumenti granulosi causa quod a carne strato membranaceo divisum est, ex quo squamulae densae granulosae oriuntur, glabro subsericeove ac pallide alutaceo supra annulum; annuli persistentis superficie supera sericea vel pallide alutacea; sporis albis in cumulo, 3.5–5 (5.5) × 2.8–3.6 (4) μ, levibus, amyloideis; basidiis 18–22 × 4–5 μ, tetrasporis; cystidiis nullis; textura tramali lamellarum ex hyphis subparallelis vel in parte media subintertextis consistente; cuticula e catenulis hypharum globosarum vel ellipsoidearum et hyphis cylindricis sparsis consistente, obscure cinnamomeae KOH ope. Habitatio: ad humum, muscos, acus et ligna coniferarum putridissima in silvis acerosis vel mixtis, vere et autumno in parte occidentali Americae Borealis.

Pileus 2–5 cm. broad, obtuse to somewhat convex when young, the margin incurved, expanding to campanulate or expanded-

umbonate, the umbo sometimes abrupt and conspicuous, the margin at first decorated with membranous flaps of the veil remnants, surface dry and at first covered with erect granulose scales, finally becoming more or less evenly granulose or powdery or the scales persistent around the disc, color evenly "Sanford's brown" to "amber brown" when fresh, between "russet" and "ochraceous tawny" when dried (almost ferruginous when fresh, duller rusty brown when dried); flesh thick in the disc, thin toward the margin, whitish to tinged with the color of the pileus, odor and taste not distinctive or at times subnauseous; lamellae adnate to rounded-adnexed, close, 2–3 tiers of lamellulae, narrow to moderately broad, whitish or tinged buff, when dried "pinkish buff," edges even; stipe 3–6 (8) cm. long, 3–7 mm. thick at apex, usually enlarged downward or base narrowly clavate, sometimes equal or nearly so, fleshy and solid, pallid to yellowish within, sheathed up to the flaring membranous annulus with a granulose covering similar in texture and color to the granules of the pileus, the sheath composed of an inner membranous layer on which are the closely arranged granular scales, scales smaller and more poorly formed downward, glabrous and somewhat silky above the annulus and pallid to pale buff, dull tawny above the annulus in dried carpophores, base often conspicuously white-mycelioid; annulus persistent, upper surface silky and pallid to pale buff.

Spores white in mass, 3.5–5 (5.5) × 2.8–3.6 (4) μ, broadly ellipsoid to nearly drop-shaped, smooth, amyloid; basidia four-spored, 18–22 × 4–5 μ, hyaline in KOH, yellowish in iodine; pleurocystidia and cheilocystidia not differentiated; gill trama of parallel hyphae or the central portion becoming somewhat interwoven, yellowish in iodine; pileus trama floccose, interwoven, pale tawny brownish under the cuticle, paler to hyaline toward the subhymenium, interwoven, yellowish in iodine, the hyphae with clamp connections; cuticle of pileus composed of chains of globose to ellipsoid cells 10–40 μ in diameter or 20–40 × 10–25 μ, some pear-shaped and a few cylindric to subcylindric, the cells very dark rusty cinnamon in KOH (cap surface becomes almost blackish if KOH is applied directly to it).

Habitat. — Scattered, gregarious, or subcespitose on humus, moss beds, needle carpets, or very rotten conifer logs in conifer forests of Douglas fir, pine, or balsam fir or in mixed forests of conifers and hardwoods (alder and cottonwood). Along our west coast it occurs at

elevations from sea level up to 5,000 feet. It fruits most abundantly from September to November along the coast of Washington and Oregon, but it has also been collected in late March in southern Oregon.

Distribution. — Western United States. It is known from California, Oregon, Washington, Idaho, and Colorado.

Material studied. — The following collections of fresh material have been studied and deposited in the University of Michigan Herbarium: Smith, 4305, 8076, 8084, 8254, 8746, 8908, 17056, 17100, 17272. The last is designated the type, and part has been deposited at the Farlow Herbarium. The following collections of dried specimens have been examined: J. M. Grant, Marysville, Washington, Oct., 1931, distributed as *Armillaria focalis* (FH). Zeller, 9180, Oregon (UM, Z). Rogers, Corvallis, Oregon, Nov., 1937 (UM, Z). Gruber, 18-5, March 28, 1942, Takilma, Oregon (UM). Epling, 96, Oregon (UM); 1221, Idaho (UM). Kauffman, Tolland, Colorado, Sept. 11, 1920, as *L. amianthina* (UM). Stuntz, 190, 403, Washington (UW).

Observations. — Kauffman's collection from Colorado is paler in the dried condition than the other collections cited above and appears to be an intermediate form connecting this species with *C. amianthinum*. In the character of its veil *C. fallax* is very similar to *C. granosum*, and the spores of both species are also somewhat alike in both size and shape. The two differ distinctly in color and habitat and to some extent in stature, but the last character is quite variable. So far as is known, the range of each also serves to distinguish them. In many respects *C. fallax* also resembles *C. carcharias*, but the reaction of the cuticle in KOH as well as the color of the pileus sharply separates it.

12. Cystoderma granosum (Morg.), comb. nov.

Agaricus granosus Morgan, Journ. Cincinnati Soc. Nat. Hist., 6 : 63. 1883.
Lepiota granosa Saccardo, Syll. Fung., 5 : 48. 1887.
Armillaria granosa Kauffman, Pap. Mich. Acad. Sci., Arts, and Letters, 2 (1922) : 60. 1923.

Illustrations:
Plate V; Text Figure 12, spores (p. 84).
Hard, The Mushroom, Edible and Otherwise, Its Habitat and Its Time of Growth, pl. vii, fig. 36.
Kauffman, Agar. Mich., Vol. II, pl. cxxix.
Marshall, The Mushroom Book, pl. 12, opposite p. 63.
Morgan, Journ. Cincinnati Soc. Nat. Hist., Vol. VI, pl. 3, upper figs.

Pileus 40–90 mm. broad, ovoid to convex when young, expanding to obtusely umbonate, broadly convex or nearly plane, margin somewhat incurved at first, surface dry and either more or less covered with small granulose scales or merely pulverulent or furfuraceous, sometimes more or less rugose-wrinkled, "ochraceous orange" (bright orange) on the disc, paler and more ochraceous yellow toward the margin or evenly colored over all; flesh thick, whitish or tinged ochraceous, odor not distinctive, taste not recorded; lamellae bluntly adnate to slightly adnexed, narrow (5–6 mm.), crowded, white to pallid tan, edges even; stipe 5–10 cm. long, 8–15 mm. thick, equal or tapering upward from a clavate base, straight or curved, fibrous-stuffed but becoming hollow, peronate by a granulose-furfuraceous sheath terminating in a median to superior rather large flaring or reflexed membranous and persistent annulus, sometimes the sheath broken into several annular zones, and usually more or less concolorous with the pileus over the outer surface, the inner or upper surface of the annulus silky and pallid orange buff, surface of stipe above annulus more or less pruinose and pallid to brownish.

Spores white in mass, 4–5 × 3 μ, ellipsoid, amyloid, smooth; basidia four-spored, 18–22 × 3.5–5 μ, yellowish orange in iodine, hyaline in KOH; pleurocystidia not differentiated; cheilocystidia basidium-like or occasionally up to 6–8 μ broad, thin-walled, clavate, hyaline, smooth; gill trama homogeneous or nearly so and of more or less parallel hyphae, hyaline in KOH; pileus trama with a cuticle of chains of inflated globose to ellipsoid cells 10–40 × 10–30 μ, their walls dark to pale reddish brown in KOH and slightly but irregularly thickened, few cylindric hyphae present in the cuticle, tramal body of filamentous hyphae bearing clamp connections and hyaline in KOH near the subhymenium, pale tan under the cuticle, lactifers present and reddish tawny in iodine, the remainder of the hyphae yellow in iodine.

Habitat. — Gregarious to cespitose on rotten wood of deciduous trees such as maple, birch, and beech. Fruiting occurs during the late summer and fall. On the basis of our records it is most likely to be found around the middle of September. In some regions, such as the Adirondack Mountains of New York and the hardwood forests of northern Michigan, it often grows in considerable abundance, but, in general, seems to be one of the less common species.

Distribution. — It is known only from central and eastern North America. It has been found in Ontario in Canada and in Michigan, Ohio, New York, and Tennessee in the United States.

Material studied. — The following collections were studied in the fresh condition: Smith, Rock River, Michigan, Sept. 22, 1929 (FH, UM). Mains, 32–765, Harbor Springs, Michigan, Sept. 14, 1933 (UM). Smith, 33–969, Porcupine Mts., Michigan, Sept. 14, 1933 (UM); 847, Pack Forest, Warrensburg, New York, Sept. 12, 1934 (UM), and 1017, 1069, same locality, Sept. 16, 20, 1934 (UM). The following collections of dried material have been examined: Kauffman, Ithaca, New York, Sept. 6, 1903 (UM); Pellston, Michigan, Sept. 9, 1905 (UM); Bay View, Michigan, Sept. 7, 1905 (UM). Kauffman and Mains, North Elba, New York, Sept. 14, 1914 (UM). Kauffman, Elkmont, Tennessee, Sept. 19, 1916 (UM); North Elba, New York, Sept. 14, 1919 (UM). Kelly, 1844, Magnetawan, Ontario, Canada, late August, 1922 (UM); 871, Magnetawan, Ontario, Sept. 7, 1920 (UM); and 146, Parry Sound District, Ontario, Sept., 1919 (UM). Walters, Cleveland, Ohio, Oct. 19, 1941 (UM).

Observations. — No attempt has been made to distinguish a rugulose form from the typical form in this species because the character usually appears on at least some of the carpophores of any collection, and old pilei lacking it appear to be rare. This species is most closely related to *C. fallax*, which, apparently, has been identified as *L. granosa* by some Pacific Coast mycologists. For a comparison of the two see *C. fallax* (p. 116). In *C. granosum* the presence of cheilocystidia and lactifers in the flesh of the pileus are additional aids in identification if one is limited to herbarium specimens. The photograph published by Marshall (*loc. cit.*) is excellent for the young stages.

13. Cystoderma subvinaceum A. H. Smith, sp. nov.

Pileo (8) 10 25 mm. lato, subconvexo, granuloso-furfuraceo vel verrucoso-squamuloso, ad marginem subappendiculato, obscure opaco-vinacco-fusco, demum gradatim pallidiore; carne alba pallidave, haud discolorante; lamellis confertis vel subdistantibus, angustis vel moderate latis, adnatis vel subdecurrentibus, latissimis in interiore parte tertia, pallidis vel alutaceis, aciebus integris; stipite 30–50 × 3–5 mm., latiore ad basin, solido, intus pallido, annulo fugaci, laccro, sericeo, supra annulum pallide vinaceo, infra annulum vesti-

mento subfibrilloso-granuloso pileo concolori obtecto, vestimento dein rupto et zonas annuliformes squamasque subrecurvatas formante, supra annulum pallide sordideque vinaceo et subpruinoso; sporis hyalinis, amyloideis, 3.5–4.2 × 2–2.3 μ, oblonge ellipsoideis; cystidiis nullis vel haud distinctis, basidiiformibus; cellulis cuticulae inflatis, globosis, subglobosis, ellipsoideis, subcylindriaceis, pallide olivaceo-griseis KOH ope. Habitatio: singulatim ad ligna putrida in Canada in America Boreali.

Pileus (8) 10–25 mm. broad, obtuse to convex, soon broadly convex to nearly plane or at times the disc slightly depressed, surface dry and granulose-furfuraceous or covered with small wartlike scales, margin at first slightly appendiculate, soon denuded and merely granulose to subtomentose, color very dark dull vinaceous brown (near "Hay's brown") at first, gradually becoming paler in age, pale vinaceous with slightly darker vinaceous brown ("fawn-color") disc, the remainder "vinaceous buff," scales or warts usually slightly darker than the ground color; flesh white to pallid and remaining pallid in dried specimens, no color changes noted, odor not distinctive, taste not recorded; lamellae close to subdistant, 42–48 reach the stipe, 2–3 tiers of lamellulae, narrow to moderately broad, bluntly adnate to subdecurrent and broadest near the stipe, pallid or tinged buff, not discoloring on drying or "pinkish buff" when dried, edges even; stipe 3–5 cm. long, 3–5 mm. thick at apex, slightly enlarged downward to a clavate base, solid, pallid within (whitish), surface sheathed up to the superior evanescent ragged annulus with a subfibrillose-granulose sheath similar in color to the scales of the pileus, the sheath soon torn up into subannular zones or somewhat recurved scales, pallid dull vinaceous and subpruinose above the annulus; annulus silky and pallid vinaceous above when well formed, concolorous with the pileus on the margin or under side, soon evanescent.

Spores hyaline in KOH, amyloid, 3.5–4.2 × 2–2.3 μ, narrowly ellipsoid; basidia 16–18 × 3.5–4 μ, four-spored; pleurocystidia not seen, cheilocystidia hardly differentiated, basidium-like and 3–5 μ in diameter at the apex; gill trama of more or less parallel hyphae, the subhymenium of narrow much-branched hyphae, dull rusty brown in all parts (hymenium, subhymenium, and flesh) in iodine; pileus trama with a cuticle of inflated to elongated cells 25–50 × 10–20 μ (some globose, some ellipsoid, some cylindric), pale

olivaceous gray when revived in KOH, dull rusty brown in iodine; clamp connections present.

Habitat. — Scattered on mossy rotten logs. September. Rare.

Distribution. — Lake Timagami region of Ontario, Canada.

Material studied. — Smith, 4755, coll. Roy F. Cain, Lake Timagami, Ontario, Sept. 10, 1936 (UM), type. Smith, 4560, same locality, Sept. 5, 1936.

Observations. — The outstanding features of this species are the habitat, the amyloid spores, and the color the cells of the cuticle assume when revived in KOH. The species appears to resemble *C. haematites* in some respects but differs in its unchanging gills and pallid flesh of the stipe as well as in its narrow spores. There should also be a distinct difference in the color of the carpophores, but we have not seen fresh specimens of the European species to verify it. The habitat of *C. subvinaceum* on decaying logs is an additional difference evident from the descriptions.

14. *Cystoderma haematites* (Berk. & Br.) Kühner et Maire, Bull. Soc. Mycol. Fr., 50 : 14. 1934.

Agaricus haematites Berkeley and Broome, Ann. and Mag. Nat. Hist., Ser. 5, 1 : 18. 1878.
Armillaria haematites Saccardo, Syll. Fung., 5 : 77. 1887.
Lepiota haematites Ricken, Die Blätterpilze, 1 : 328. 1913.

Illustrations:
Bresadola, Icon. Mycol., pl. 49, fig. 1.
Cooke, Illus. Brit. Fungi, no. 54, pl. 45.
Konrad et Maublanc, Icon. Sel. Fung., Vol. III, pl. 202, as *Collybia lilacea* Quélet f. *robusta*.

"P. 2–4 cm. *red liver colour*, hemispherical, then somewhat flattened, or depressed at the centre, thin, *slightly hispid*, becoming smooth. St. 4–6 cm. × 3–5 mm., *concolorous below the ring, whitish above*, equal; base *thickened*, white floccose. Ring *whitish, then concolorous*, submembranaceous, narrow, inferior, scaly beneath, torn, often fugacious. Gills *white then whitish tinged with rose*, and becoming rose colour when rubbed, sinuato-adnate, or shortly decurrent, scarcely crowded, narrow, 3 mm. broad. Flesh *pale liver colour, slightly yellowish in the st.* Spores white, ovoid-ellipsoid, 4 × 3 μ."

Habitat. – Gregarious to cespitose on moss and needle carpets under firs. Late fall. Rare.

Distribution. — England, France, and Italy.

Material studied. — None.

Observations. — The description is quoted from Rea (1922). Kühner and Maire (1934) state that the spores are amyloid. *C. subvinaceum* appears from the descriptions to resemble *C. haematites* in some respects. For a comparison of them see page 122. Konrad and Maublanc (*loc. cit.*) have illustrated an exannulate form of *C. haematites* under the name *Collybia lilacea* Quélet (f. *robusta*). The true *C. lilacea* Quélet is now considered a synonym of *Baeospora myriadophylla* (Pk.) Singer.

Excluded and Doubtful Species

Agaricus (*Lepiota*) *polyglonus* Berk. & Br., Journ. Linn. Soc., 11 : 509. 1871. This is described as allied to *Ag. granulosus.* We have not seen specimens, and the information on it is meager.

Cystoderma Bucknallii (Berk. & Br.) Singer, *Schweizer. Zeitschr. Pilzk.*, 17:53. 1939. Retained in Lepiota.

Cystoderma echinata (Fr.) Singer, *Schweizer. Zeitschr. Pilzk.*, 17 : 53. 1939.

Cystoderma Eyrei (Massee) Singer, *Schweizer. Zeitschr. Pilzk.*, 17 : 53. 1939.

Cystoderma fumoso-purpurea (Lasch) Fayod, *Ann. Sci. Nat.*, Sér. 7, 9 : 351. 1889.

Cystoderma Hetieri (Boud.) Singer, *Schweizer. Zeitschr. Pilzk.*, 17 : 53. 1939.

Cystoderma ochracea (Bull.) Fayod, *Ann. Sci. Nat.*, Sér. 7, 9 : 410. 1889. If recognized as validly published it would become a synonym of *C. amianthinum.*

Cystoderma seminudum (Lasch) Fayod, *Ann. Sci. Nat.*, Sér. 7, 9 : 351. 1889.

Lepiota amianthina var. *Broadwoodiae* (Berk. & Br.) Saccardo, *Syll. Fung.*, 5 : 48. 1887. If the description of the pileus is correct, it cannot be a variety of *C. amianthinum* and may not be a Cystoderma.

Lepiota asprata (Berk.) Saccardo, *Syll. Fung.*, 5 : 48. 1887.

Lepiota carcharias var. *incarnata* Saccardo, *Fung. Ital. Crypt.*, 1 : 83. 1915. Apparently this is a *nomen nudum.* It was taken from a manuscript of Bresadola's.

Lepiota Terreji (Berk. & Br.) Saccardo, *Syll. Fung.*, 5 : 47. 1887.

This was originally described as *Ag. Terreii* Berk. & Br., *Ann. Mag. Nat. Hist.*, Ser. 4, 6 : 462. 1870, and is found in Rea as *Lepiota cinnabarina* var. *Terreyi*. From the illustration by Saunders and Smith, *Mycol. Illus.*, pl. 35, figs. 1–5, we might think it only a color form of *cinnabarinum*, but we have no data on cystidia or iodine and KOH reactions. Consequently, it cannot be placed in our classification.

Lepiota granulosa var. *rufescens* (Berk. & Br.) Saccardo, *Syll. Fung.*, 5 : 47. 1887. Apparently this is a true Lepiota.

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Cystoderma granulosum var. *typicum*, f. *typicum*. × 1

Cystoderma carcharias f. *album* (Fr.) Smith & Singer. × 1

Cystoderma amianthinum f. *rugosoreticulatum* (Lorinser) Smith & Singer. × 1

Cystoderma fallax Smith & Singer. × 1

Cystoderma granosum (Alexy [illegible]) Harmaja & Singer / [illegible]

(Photograph by courtesy of Maurice B. Walters)

THE GENUS LIMACELLA IN NORTH AMERICA

HELEN V. SMITH

Introduction

THE present study represents the first part of an investigation of the North American species of Lepiota. My interest in the genus was first aroused during the fall of 1937, when I accompanied my husband, Dr. Alexander H. Smith, on a collecting expedition to northern California. On subsequent collecting trips I began a critical study of the genus with the hope that I might become familiar with our North American species. Since these fungi are generally sporadic in their appearance, field work must be spread over a rather long period of years to be of much value in establishing the distribution of any species and its relative abundance in the Lepiota flora. Fortunately, circumstances have favored this approach to the study of the genus. In addition to field work carried on from 1937 through 1941 my investigation has been greatly facilitated by access to the Lepiota collections in the University of Michigan Herbarium and by authentic material borrowed from other institutions.

One of the first features about Lepiota to impress me was the presence in the genus of certain very distinct groups of species. Another was the great diversity of the microscopic characters, such as the shape of spores and the type of cuticle on the pileus. One group was found to differ sharply from the majority of the species in having divergent gill trama. This character was also correlated with subviscid to glutinous pilei. These species were chosen for particular study because it seemed very apparent that they were by no means "typical" of Lepiota. A survey of the literature indicated that from the time of Fries mycologists had been puzzled by the relationships of the group and that several attempts to arrange them in a more natural classification had already been made. Since the number of species with divergent gill trama is relatively small and since, with two exceptions, they are all somewhat rare, herbarium material had to be relied upon to a larger extent than will

be necessary in future studies in Lepiota. From the material and information available, however, it was evident that the group does represent a distinct and natural genus and that its relationships are with Amanita rather than with Lepiota.

HISTORY

Two of the species, *Lepiota illinita* and *L. delicata*, now included in Limacella were originally placed by Fries (1821) in the tribe Lepiota of Agaricus. He later (1874) included these with *Agaricus medullatus*, *A. gliodermus*, *A. pinguis*, and *A. inoculatus* in his section Viscosae of Lepiota. He also placed in the tribe Amanita *A. lenticularis* (*guttatus*), *A. Persooni*, and *A. aridus*, the first of which is now definitely known to belong in Limacella, thus making it evident that he was aware of their close relationship to the typical Amanitae. Quélet (1888) united with the species mentioned above all other known viscid species of Lepiota. Earle (1909) was the first who validly published the genus Limacella. Myxoderma Fayod (1889) and Amanitella Maire (1913) are untenable. Maire, however, was the first to define Limacella precisely in such a way that it included a group of obviously closely related species. He pointed out that the presence of divergent gill trama was the important character and that because of it the genus was more closely related to Amanita than to Lepiota in the restricted sense. Earle merely characterized the genus as: "Putrescent, solitary or gregarious: pileus fleshy, viscid, discrete from the stipe: lamellae free: spores white: veil forming an annulus: stipe central, slender, fleshy, no cortex." He selected *L. delicata* as the type. Two of the characters he mentioned deserve some comment. The pileus is supposed to be discrete from the stipe, a character of both Amanita and Lepiota but, apparently, this is not too distinct in *L. glioderma*. The lamellae are supposed to be free, but, again, in *L. glioderma* and other species now placed in the genus they are slightly attached. These reasons led Quélet to place *L. glioderma* in Armillaria.

Maire (1913) published the results of a careful histological study on four viscid species of Lepiota: *L. lenticularis*, *L. illinita*, *L. glioderma*, and *L. irrorata*. He found that the first three had an amanitoid gill structure, i.e. bilateral trama, whereas the fourth had the typical regular trama and cheilocystidia usually found in the true Lepiotae. As a result of this study, while unaware of Earle's prior

name he proposed the name "Amanitella" to include the species characterized thus: carpophores without a volva, annulate, cuticle of pileus separable, viscid; trama of gills bilateral, lamellae rounded toward the stipe. These species differ from Amanita principally by the lack of a volva and by the presence of rounded lamellae, and from Lepiota in having bilateral trama. He selected *L. lenticularis* as the type and included *L. illinita* and *L. glioderma*. Maire (1914) later adopted the name "Limacella" for his genus. From the information available at present there appears to be no good reason for excluding *L. glioderma*. The genus as originally defined by Earle obviously included any viscid Lepiota, and in this respect was as artificial as the arrangement it was designed to supersede. Furthermore, the two characters in question do not now appear to be as important as has been assumed by some investigators. The gills are slightly attached in some true Amanitae and, so far as is known (Kühner, 1936), there is not a really distinctive anatomical difference between species like *L. glioderma*, in which the stipe is not obviously readily separable from the flesh of the pileus, and the species of Amanita which possess this character. Consequently I have followed Maire's disposition of the species named above. Murrill (1914) recognized the genus Limacella in the sense of Earle and included nine species. Kauffman (1924) did not recognize the genus but, instead, placed all viscid species in the sections Lubricae and Viscidae, regardless of the nature of the gill trama. Kühner (1936) recognized the genus in the sense of Maire, and this is also the concept as recognized by Singer (1939) in his studies of the genera of the Agaricales. Since this concept is the one most accurately expressing the limits and natural relationships of the genus, it is accepted here.

DESCRIPTION OF LIMACELLA

Pileus fleshy, putrescent, variously shaped but usually convex to obtusely umbonate or nearly plane, surface subviscid to glutinous, glabrous, sometimes appearing fibrillose-streaked beneath the gluten, sometimes appressed or crustose-scaly, color variable, white, cream color, grayish, grayish olive, pinkish to deep reddish brown; flesh often thick in the disc, usually thin elsewhere, soft, often with a farinaceous or otherwise distinctive odor or taste; lamellae free or sinuate and attached by a line or deeply adnexed, moderately

broad and close, thin, usually white or at least paler than the pileus; stipe fleshy, central, more or less readily separable from the tissue of the pileus, often sheathed with the remains of a glutinous to merely viscid universal veil, sometimes dry, annulus usually present, sometimes persistent and sometimes not forming, or merely present as a superior somewhat fibrillose zone from the thin fibrillose partial veil.

Spores white, small, usually globose to subglobose, 3.5–4.5 μ in diameter but in some broadly ellipsoid and up to 6–7 μ long, no germ pore present, nonamyloid, smooth or in some appearing finely stippled under an oil-immersion lens; basidia usually four-spored; neither pleurocystidia nor cheilocystidia differentiated but the gill edges often with sterile basidium-like cells; gill trama clearly bilateral, either with or without a central strand, subhymenium parenchymatous, lactifers present or absent; pileus trama loosely floccose, lactifers present in some, clamp connections present; cuticle of pileus differentiated into a more or less turflike covering, the apical cells of the component hyphae attenuated, narrowly clavate to cylindric or in some species narrow and greatly elongated, more or less gelatinous.

As defined here, all viscid Lepiotae with regular gill trama are excluded. From species of Armillaria with divergent gill trama the Limacellae are distinguished by the nonamyloid and very small spores, the free or nearly free gills, and the more slender stature. The Armillariae in question are mostly large hard-fleshed species with long-decurrent to broadly adnate gills. From Amanita Limacella is distinguished by its lack of a volva and its very small spores. Cystoderma is excluded because of its regular gill trama and dry granulose pilei, although some tendency toward the production of sphaerocysts was noted on the cuticle of *L. roseicremea*. Amantiopsis, if considered distinct from Amanita, differs in the presence of a volva and the lack of an annulus.

COMMENTS ON THE CHARACTERS OF THE SPECIES

In general, the plants of this genus are quite similar in appearance, but the colors are not especially attractive, although they do furnish one of the chief characters by which species are recognized. A rather wide range of variation, however, must be allowed. The character of the surface of the stipe, whether viscid to glutinous or dry, is the major difference and the one by which the genus is divided into

two sections. The color of the gluten — hyaline, yellow, or red — has been given emphasis, and considerable importance has been attached to the color changes that take place in the gluten of the stipe in the *L. illinita* series. Although the characters of the annulus, particularly whether it is persistent or evanescent, have been somewhat emphasized, these still need to be confirmed by a study of more fresh material in the Lubricae. In the Viscidae, those with dry stipes, the annulus received some prominence in the classification. Two series of species are represented, one containing *L. lenticularis*, in which the annulus is large, flaring, and persistent, and the other, represented by *L. gliodɛrma*, with evanescent or poorly formed annuli.

Aside from the viscidity or glutinous nature of the surface of the pileus, the macroscopic characters of the cuticle are of secondary importance. The color, when not located in the cuticle, is in the hyphae just beneath it. The pilei are usually glabrous, but in weathered specimens some checking may occur to produce crustose scales or radial cracks. The characters of the lamellae are mostly of secondary importance. In *L. oblita*, however, the gills are said to be forked, and this may prove to be of some significance. Considerable emphasis has been placed on taste and odor since, from the information available, they appear to be quite constant. It may eventually be found desirable to use them as characters for the recognition of varieties rather than species.

Although established on the character of the gill trama, Limacella possesses few microscopic characters of major importance in the classification of its species. The spores are all small and mostly globose to subglobose. In some species they appear to be finely stippled, but the character is so difficult to observe that it is questionable whether it can ever be used to advantage. Pleurocystidia and cheilocystidia are not differentiated. In the cuticle of the cap important microscopic differences are rather useful in the recognition of species. There are two main types of cuticle. In such species as *L. lenticularis* and *L. solidipes* the terminal cells are fairly broad and short and become narrowed toward the ends. These are borne at the ends of chains of short-cylindric cells and resemble filaments of Rivularia. A slight variation occurs in *L. roseicremea*, in which the cells beneath the terminal cells are sometimes slightly inflated and nearly globose. A second type is clearly seen in such species as

L. glischra. Here the terminal cuticular elements are narrow, usually not over 4 μ in diameter, and remain of the same width throughout their length. They are longer than the terminal cells of the first type and usually stand erect and closely packed, forming a turflike covering 50–200 μ in thickness. The long cells may become appressed, when they are hard to distinguish, and may also give a streaked appearance to the pileus.

GENERAL CONSIDERATIONS

As a result of this study twelve species and three varieties of Limacella have been recognized in the agaric flora of North America. One new species and one new variety have been described. Murrill, in his account (1914) of the genus, treated nine species, three of which are no longer included in Limacella. With the exception of *L. agricola*, *L. delicata*, and *L. oblita* material of all the species included in this paper has been examined. Eleven are known to occur in the United States; one other is recorded only from the type locality in Jamaica. Only two species, both of which are northern in their distribution, appear to be relatively common in our agaric flora. Both *L. glioderma* and *L. illinita* occur across the continent in southern Canada and the northern United States; their range extends southward to California in the West and the Great Smoky Mountains in Tennessee and North Carolina in the East. *L. glioderma*, or a form of it, also occurs in Florida. *L. roseicremea* is known only from the type locality in Washington. *L. solidipes*, described from New York, has also been found in Washington and California. *L. glischra* is known from Ohio, Tennessee, and North Carolina in the East and from California and Washington in the Western states. Three species are reported only from the South — *L. roseola* from Virginia, *L. floridana* from Florida, and *L. Kauffmanii* from Virginia and Tennessee. In all, about seventy-five collections have been studied in either the fresh or the dried condition. These records, however, cannot be regarded as establishing the true pattern of distribution of the majority of the species, but, rather, indicate the areas where collecting has been most intensive.

The color names in quotation marks are taken from R. Ridgway, *Color Standards and Color Nomenclature* (Washington, D.C., 1912). All collections studied, except borrowed type material, are deposited in the herbarium of the University of Michigan.

I wish to express my appreciation to Dr. E. B. Mains, director of the University of Michigan Herbarium, who has placed the collections of Lepiota in the herbarium at my disposal. My husband, also of the herbarium, has turned over to me his unidentified specimens of Lepiota and Limacella as well as his field notes on the genus. His suggestions and comments have also proved helpful in the preparation of the manuscript. Dr. W. A. Murrill, of Gainesville, Florida, was most generous in sending to me the type collections of three species which he recently described from Florida.

KEY TO SECTIONS

I. Stipe viscid or glutinous ..... Lubricae
II. Stipe dry ..... Viscidae

KEY TO SPECIES

LUBRICAE

I. Terminal cells of cuticular hyphae usually 3–5 μ in diameter at the base; apices at times somewhat attenuated
  A. Pileus bright yellow brown or reddish brown
    1. Gluten of stipe "burnt sienna" (bright reddish brown) 1. *L. glischra*
    2. Gluten of stipe "ocher yellow" (yellow) ..... 2. *L. Kauffmanii*
  B. Pileus dull brown to isabelline
    1. Gills not forked; spores globose ..... 3. *L. floridana*
    2. Gills forked; spores ellipsoid ..... 4. *L. oblita*
  C. Pileus white or disc tinged yellowish to pallid alutaceous or grayish 5. *L. illinita*
    1. Pileus white to cream color, only slightly yellowish in dried material ..... var. *typicum*
    2. Pileus grayish brown to pale clay color on the disc, brownish when dried ..... var. *argillacea*
    3. Pileus white to cream-colored, but gluten staining reddish; flesh with farinaceous taste ..... var. *rubescens*
II. Terminal cells of the cuticular hyphae usually 5–10 μ in diameter at the base; apices commonly attenuated ..... 6. *L. roseicremea*

VISCIDAE

I. Pileus white, slimy, 2.5 cm. broad; known only from Jamaica 7. *L. agricola*
II. Known from temperate regions
  A. Spores strongly pseudoamyloid; pileus rose pink ..... 8. *L. roseola*
  B. Spores not or only slightly pseudoamyloid; pileus not truly pink or pinkish (some are reddish brown)
    1. Annulus membranous, flaring and persistent; pileus white to buff-colored
      a. Gills or some other part of carpophore often stained olivaceous gray, at least in age; odor not distinctive .... 9. *L. lenticularis*

b. Gills not staining; odor strong when carpophores are drying, resembling that of coal tar or *Tricholoma sulfureum* var. *Fischeri*

c. Pileus white at first, odor and taste strongly farinaceous 10. *L. solidipes*

2. Annulus usually evanescent or ragged
   a. Odor and taste strongly farinaceous ..... 11. *L. glioderma*
   b. Odor and taste not farinaceous ..... 12. *L. delicata*

1. *Limacella glischra* (Morgan) Murrill, North Am. Flora, 10 : 41. 1914.

Lepiota glischra Morgan, Journ. Mycol., 12 : 203. 1906.

Pileus 2–4 cm. broad, convex or with a slight umbo, covered with a slimy viscid layer of gluten which is near "burnt sienna" in color, pale beneath the gluten, margin appendiculate from glutinous patches of the universal veil, flesh white, thick and soft in texture; lamellae close, broad, approximate, rounded toward the stipe, white, edges even; stipe 6–8 cm. long, 9–12 mm. thick at apex, equal or tapering slightly at the base, solid, surface covered with a thick layer of gluten similar to that on pileus, flesh white, base white-cottony, annulus evanescent, not membranous.

Spores spherical to subglobose, 3–4.2 μ in diameter, very pale yellowish brown in iodine, appearing finely stippled under oil immersion as though the wall were punctate or very finely echinulate; basidia 18–27 × 6–7 μ, four-spored; neither pleurocystidia nor cheilocystidia present; gill trama of divergent hyphae of approximately uniform width (4–8—10 μ in diameter), no distinct central strand, the cells usually very loosely arranged, the subhymenium composed of very small compact cells 2–3 layers in depth; pileus trama of loosely interwoven hyphae of variable diameter, from 6–19 μ wide, lactifers present, clamp connections present, cuticle of very closely interwoven hyphae (2)4–5 μ wide, with free ends obtuse, very compact, at times upright and occasionally appressed, trama below cuticle of similar hyphae but more loosely arranged.

Habit, habitat, and distribution. — Single on rich soil under conifers or hardwoods; North Carolina, Tennessee, Ohio, California, and Washington.

Observations. — This fungus may be readily recognized by the thick coat of bright reddish gluten that covers the entire plant. The gluten may be so thick that it drips off the cap at the margin.

This is particularly true in wet weather, when much moisture has been absorbed.

The spores appear finely stippled when stained in iodine and studied under oil immersion, but the wall does not appear to be roughened. Since several other species exhibit this same stippling and since it is very difficult to observe even under an oil-immersion lens, this character is not at present considered diagnostically important.

2. **Limacella Kauffmanii,** sp. nov.

Pileus 2–7.5 cm. latus, glutinosus, rufus, ad marginem subflavidus; lamellae pallidae, confertae, subliberae; stipes 3–7 cm. longus, 3–5 mm. crassus, glutinosus; velum glutinosum, flavidum; sporae 4–5 × 3 μ. Specimen typicum in Herb. Univ. Mich. conservatum; legit C. H. Kauffman, Chain Bridge, Virginia, 1919.

Pileus 2–7.5 cm. broad, broadly oval at first, becoming obtuse, finally expanded and with a broad, low umbo, bay brown with a broad "raw sienna" margin when young, margin fading to "antimony yellow," covered with a thick pale-yellow layer of gluten, surface beneath the gluten somewhat streaked with stripes of lighter and darker yellowish brown, gluten mild in taste, surface even, splitting radially on the margin on drying, flesh white or pallid, cottony, somewhat watery at first, becoming thin abruptly halfway to the margin, odor none, taste subfarinaceous and subastringent or none; lamellae equal, close to crowded, not broad (3–5 mm.), appearing free but adnexed by a narrow strip, at first white, becoming sordid whitish, deeply emarginate-rounded toward the stipe, abruptly narrow toward the margin, edge entire, thin; stipe 3–7 cm. long, 5–9 (10) mm. thick, equal or tapering upward, 3–5 mm. at apex, glutinous from the "yellow ocher" universal veil, apex almost naked, the gills terminating in a minutely floccose small circular ridge running around the stipe, surface at length subfloccose from the drying gluten, a brownish glutinous narrow annulus at times marked by the collapsing of the inner and outer veil, stipe brunnescent from dried gluten, stem solid and pallid within.

Spores 4–5 × 3 μ, broadly ellipsoid to subglobose, light yellow in chloral hydrate-iodine solution; basidia about 30 × 6 μ; no pleurocystidia, cheilocystidia basidium-like; pileus trama mostly spongy but with a compact brownish layer beneath the cuticle,

cuticle composed of a turf of more or less upright hyphae 3–4 μ in diameter and with the terminal cells 150–200 μ long; gill trama divergent.

Habit, habitat, and distribution. — Single, gregarious or subcespitose in woods of oak or maple; Virginia and Tennessee.

Observations. — Although apparently quite similar to *L. glischra*, this fungus may readily be distinguished from it in the field by the distinctly yellow copious gluten which covers the entire plant. When dried the two species resemble each other closely. Kauffman collected a specimen at Chain Bridge, Virginia, in 1919 and tentatively identified it as *Armillaria megalopoda*. A. H. Smith later found *L. Kauffmanii* in the Great Smoky Mountains National Park, so that it appears to be southern in distribution.

3. **Limacella floridana** (Murrill), comb. nov.

Armillaria floridana Murrill, Mycologia, 35: 422. 1943.

Pileus 4.5 cm. broad, convex to plane, becoming slightly depressed, not umbonate, somewhat viscid, uneven, uniformly umbrinous-isabelline or slightly darker on disc, margin undulate-even; flesh white, unchanging, odor faint, pleasant; lamellae deeply emarginate, just touching the stipe, broad, ventricose, close, entire, inserted, white, fragile; stipe about 5 cm. long, 7–9 mm. thick, subfusiform, white, annulus median, small, white, persistent, stipe smooth, dry and glabrous above, viscid and floccose-squamulose below the annulus.

Spores globose, 3.8–4.2 μ in diameter, not staining in chloral hydrate–iodine solution, appearing minutely stippled under oil immersion; basidia 16.8–25 × 4.2–6.3 μ, four-spored; neither pleurocystidia nor cheilocystidia present; gill trama divergent, no distinct central strand (divergence difficult to demonstrate on revived sections); pileus trama with a cuticle of turflike appressed or upright hyphae with attenuated ends, below this the tissue loosely floccose, lactifers few and scattered, mostly 2.1–4.2 μ wide.

When dried the pileus is "antique brown," and the gills are "argus brown."

Habit, habitat, and distribution. — Single in humus under oak; Florida.

Observations. — The persistent annulus and umbrinous color

should distinguish this species from *L. oblita*. Neither species, however, is sufficiently well known, and the possibility of their being synonymous is by no means excluded. The microscopic data are taken from the type.

4. *Limacella oblita* (Peck) Murrill, North Am. Flora, 10 : 42. 1914.

Agaricus (*Lepiota*) *oblitus* Peck, Bull. Buffalo Soc. Nat. Sci., 1 : 41. 1873.
Lepiota oblita Saccardo, Syll. Fung., 5 : 71. 1887.

Pileus 5–7.5 cm. broad, viscid, convex or expanded, subumbonate, alutaceous inclining to tawny, faintly darker on the umbo, surface smooth or obscurely spotted or scaly from the rupturing of the universal veil; lamellae crowded, whitish or yellowish, free, sometimes forked; stipe 5–7 cm. long, about 6 mm. thick, equal or tapering slightly upward, smooth at apex, annulus obsolete, floccose and viscid below, stuffed or hollow.

Spores ellipsoid, 5–6 × 3–4 μ, smooth, hyaline; other microscopic characters unknown.

Habitat and distribution. — In deciduous woods; New York.

Observations. — No material of this species has been examined, and it is impossible to determine whether or not this plant should be included in Limacella in the sense in which the name is used in this paper. None of the characters are out of line, however, with those of the species now in the genus. It seems to be characterized by the yellowish forked gills and the floccose stipe. *L. floridana* appears to be very close.

5. *Limacella illinita* (Fries) Earle, Bull. New York Bot. Gard., 5 : 447. 1909.

Agaricus illinitus Fries, Syst. Mycol., 1 : 23. 1821.
Lepiota illinita Quélet, Champ. Jura et Vosges, p. 338. 1873.
Amanitella illinita Maire, Ann. Mycol., 11 : 337. 1913.
Amanita (subg. *Limacella*) *illinita* Gilbert, Le genre Amanita Persoon, p. 166. 1918.
Myxoderma illinita (Fries) Kühner, Le Botaniste, 17 : 144. 1926.

Illustrations:
Fries, Icon. Hymen., pl. 16, no. 1.
Bresadola, Icon. Mycol., Vol. I, pl. 42 (as *Lepiota illinita*).

Pileus 2–7 cm. broad, ovoid to obtuse when young, becoming campanulate to plane or retaining a slight umbo, surface covered

with a clear hyaline gluten which often drips from the margin of the pileus in wet weather, appearing faintly fibrillose-streaked beneath the gluten, pure white or whitish, the disc at times tinged with yellowish; flesh thin and relatively soft, white, odor and taste not distinctive; lamellae free, close, white to creamy white, narrow or becoming moderately broad (up to 1 cm. or slightly more), edges even; stipe 5–9 cm. long, 3–8 mm. thick, tapering slightly upward, fibrous, white or whitish and lower portion covered wth a thick coating of hyaline gluten which terminates in a slight annular fibrillose but soon evanescent zone, white and silky above the annular zone.

Spores globose to broadly ellipsoid, 4.5–5.5 × 5–6.3 μ, with a distinct apiculus, pale yellowish in iodine; basidia four-spored, 20–26 × 3–4 μ, hyaline in KOH; neither pleurocystidia nor cheilocystidia differentiated; gill trama divergent from a central strand, the divergent hyphae rather large and loosely arranged; pileus trama very loosely floccose, clamp connections present; pellicle of pileus of gelatinous hyphae 3–4 μ in diameter and about 120 μ long, forming a compact turf, hyaline.

Habit, habitat, and distribution. — Single, scattered, or gregarious, on soil under hardwoods or conifers, on forest débris on humus under bracken fern, on mossy soil in cedar swamps, and in fields or under beech on sand dunes. In North America it is known from Quebec in Canada and from New York, Michigan, California, Oregon, and Washington in the United States.

Observations. — Because of the copious gluten which covers the pileus and stipe, and the soft flesh, this species is difficult to collect and photograph. It is one of the two relatively common species of Limacella and occasionally occurs in considerable abundance under the luxuriant growth of bracken fern which soon overruns all clearings in the forests of our Pacific Coast region if the land is neglected. Dried specimens of var. *typica* are white or only very slightly yellowish, whereas in the following two varieties the colors are darker, at least in some parts.

Limacella illinita var. **rubescens,** var. nov.

Sapor amarifarinaceus; stipes deorsum demum rubidus vel vinaceus; velum glutinosum, saepe rubescens. Specimen typicum in Herb. Univ. Mich. conservatum; legit F. L. Drayton, Barnet, Quebec, Sept. 25, 1938.

Pileus 2.5–7 cm. broad, convex, campanulate or broadly umbonate, white, very viscid; flesh rather fragile, white, 2–7 mm. thick, odorless, taste of pellicle slightly bitter, flesh bitterish-farinaceous; lamellae narrowly adnexed, close to subdistant, white; stipe 6–10.5 cm. long, 6–8 mm. thick, equal, solid, glutinous, white above but pinkish vinaceous toward the base or gluten becoming maroon red, annulus glutinous.

The microscopic details are as given for var. *typica*.

Habitat and distribution. – On ground under spruce and balsam. It has been found in Quebec in Canada, and in New York in the United States.

Observations. — This variety is distinguished from var. *typica* by the changing gluten (to pinkish or red) on the stipe and by the taste. In dried material as well as in fresh specimens the reddish color is noticeable. The flesh beneath is white to whitish. The type was collected by F. L. Drayton, September 25, 1938, on ground under spruce and balsam at Barnet, Quebec. Kauffman found it in the Adirondack Mountains of New York.

Limacella illinita var. **argillacea** (Fries), comb. nov.

Agaricus (*Lepiota*) *illinita* var. *argillacea* Fries, Hymen. Eur., p. 39. 1874.
Amanita (subg. *Limacella*) *illinita* var. *ochracea* Gilbert, Le genre Amanita Persoon, p. 167. 1918.

Pileus fleshy, 6.5± broad, broadly and slightly umbonate, glutinous, pellicle with a pale brownish tinge, "Verona brown" on disc, shading to "cinnamon buff" or pallid at the margin; flesh white, thin, odor and taste not recorded; lamellae free, creamy white, about 1 cm. broad, edge very slightly undulate; stipe 7.5 cm. long, 8 mm. thick, tapering slightly upward, glutinous, cinnamon buff, annulus obsolete.

The microscopic characters are as given for var. *typica*.

Habitat and distribution. — Under conifers in California and Oregon.

Observations. — This variety is distinguished by the dull-brownish tinge on disc and stipe in both fresh and dried condition, but the colors are by no means so pronounced as in either *L. glischra* or *L. Kauffmanii*. The gluten is hyaline to grayish on the stipe and does not change to reddish, as it does in the previous variety.

6. *Limacella roseicremea* Murrill, Mycologia, 4 : 212. 1912.

Pileus up to 6 cm. broad, convex to plane, expanding slowly, umbo low and broad, smooth, glabrous and viscid, not striate, cream color tinged with rose, margin inflexed, flesh white, odor farinaceous; lamellae free, rather close, arcuate, white; stipe 5-10 cm. long, 12 mm. thick, enlarged at the base, white, fleshy, solid, smooth, viscid; annulus persistent, superior, ample, membranous, remaining stretched from margin to stipe for some time.

Spores 3.5–4.8 (5.2) × 3.1–4.7 μ, subglobose to broadly ellipsoid, hyaline to yellowish in iodine and very minutely punctate under oil immersion; basidia hyaline in KOH, very narrowly clavate, 18–24 × 4.5–6 μ, four-spored; pleurocystidia and cheilocystidia not differentiated; gill trama divergent; pileus trama with a cuticle as in *L. solidipes*, but some cystidium-like cells present and some almost globose and in chains but with the terminal cell attenuated, not distinctly gelatinous in KOH.

Habitat and distribution. — On ground in the woods; Washington.

Observations. — This plant evidently resembles *L. illinita* to some extent macroscopically but is readily distinguished microscopically. In *L. illinita* the cuticular elements are long and narrow, whereas in *L. roseicremea* they are much shorter and narrowed toward the ends. These cuticular cells are borne at the ends of chains of subglobose cells. The microscopic details were obtained from the type. Macroscopically the two species are distinguishable by the annulus. In *L. illinita* it is glutinous and becomes obsolete. In *L. roseicremea* the annulus is membranous, ample, and persistent and may remain stretched from the margin to the stipe for some time. This species is known only from the type locality but appears to be a really distinctive Limacella.

7. *Limacella agricola* Murrill, Mycologia, 3 : 81. 1911.

Pileus 2.5 cm. broad, convex, regular, rather firm, surface glabrous, smooth, white, slimy, margin incurved and striate; lamellae free, white, broad, unequal; stipe 2.5 cm. long, 2 mm. thick, slightly bulbous at the base, cylindric, even, white, glabrous, shining, annulus slight, evanescent, superior.

Spores 4–5 μ long, subglobose, smooth, perfectly hyaline, often uninucleate; other microscopic characters not known.

Habitat and distribution. — On a lawn; Jamaica.

Observations. — This species is very poorly known. It is pure white and much smaller than most members of the genus. It has been reported only from the type locality in Jamaica, and, since no information is available on the character of the gill trama, further collections and studies are necessary in order to determine its relationships. Its inclusion here is provisional.

8. *Limacella roseola* Murrill, Mycologia, 35 : 426. 1943.

Pileus about 5 cm. broad, convex to expanded, umbonate, rose pink with a slightly darker umbo, surface smooth, glabrous; lamellae approximate to the stipe, rose-tinted, crowded, fairly broad, edges even; stipe about 7 cm. long, slender and tapering upward, pale roseous, subglabrous, annulus evanescent, median.

Spores globose to subglobose, 3.5–4.8 × 3–4 μ in diameter, when immature appearing very finely punctate in mounts revived in chloral hydrate–iodine solution, pseudoamyloid (becoming rusty brown in the iodine solution); basidia 16.8–25 × 4.2–6.3 μ, four-spored; neither cheilocystidia nor pleurocystidia differentiated; pileus trama loosely floccose beneath the cuticle but fairly compact toward the subhymenium, lactifers numerous, contorted and branched, 4–6 μ in width, staining brown in iodine solution, clamp connections present, hyphae of cuticle narrow (2–6 μ), the end cells often somewhat enlarged near the apex, more or less decumbent and not forming a distinct turf of upright hyphae; gill trama divergent from a central strand, with numerous contorted and branched lactifers 6.3–12.6 μ wide, which stain a deep rusty brown in iodine solution.

When dried the cap is avellaneous with a tinge of cinnamon on the disc. Dr. Murrill says the cuticular hyphae are slightly gelatinous in KOH. This indicates that the pileus is likely to be at least slightly viscid when wet.

Habitat and distribution. — Growing on humus in a hollow tree; Virginia.

Observations. — The pink color of the entire fruiting body should be a good field character for this species. Microscopically it is distinguished by the pseudoamyloid reaction of the spores in chloral hydrate–iodine solution. The spores become a deep rusty brown in iodine, a reaction somewhat paler than that usually noted in Lepiota. This is a character frequently observed among the true Lepiotae

but not among the species of Amanita. The lactifers are very conspicuous in the iodine mounts.

9. *Limacella lenticularis* (Lasch) Earle, Bull. New York Bot. Gard., 5 : 447. 1909.

Agaricus lenticularis Lasch, Linnaea, 3 (18) : 157. 1828.
Lepiota lenticularis Gillet, Les Hyménomycètes, p. 66. 1874.
Amanitella lenticularis Maire, Ann. Mycol., 11 : 337. 1913.
Amanita lenticularis Lange, Bot. Arkiv, 2 (3) : 11. 1915.
Lepiotopsis lenticularis Konrad et Maublanc, Icon. Sel. Fung., Vol. I, pl. 9. 1924.
Lepiota guttata Quélet, Champ. Jura et Vosges, Suppl. 4 : 325. 1876.
Limacella guttata Konrad et Maublanc, Icon. Sel. Fung., Vol. I, pl. 9. 1924.
Agaricus megalodactylus Berkeley, Outl. Brit. Fungol., p. 91. 1860.
Amanita megalodactyla Saccardo, Syll. Fung., 5 : 20. 1887.
Lepiota lenticularis var. *megalodactyla* Rea, Brit. Bas., p. 80. 1922.
Agaricus lerchei Weinmann, Hymen. et Gast. Ross., p. 11. 1836.
Amanita (subg. *Limacella*) *lenticularis* Gilbert, Le genre Amanita Persoon, p. 160. 1918.

Illustrations:

Cooke, Illus. Brit. Fungi, No. 15, pl. 11 (as *Agaricus* [*Amanita*] *megalodactylus*).
Fries, E. Icon. Hymen., pl. 13.
Konrad et Maublanc, Icon. Sel. Fung., Vol. I, pl. 9 (as *L. guttata*).
Lange, Flora Agar. Danica, Vol. I, pl. 7, fig. A.
Smith, Pap. Mich. Acad. Sci., Arts, and Letters, 26 (1940), pl. 2. 1941.

Pileus 6–15 cm. broad, very obtuse when young, becoming broadly umbonate at maturity or the margin elevated slightly and the umbo disappearing, glabrous and viscid when young, in age the cuticle sometimes separating into fibrils and then appearing obscurely virgate, margin often splitting radially, cuticle sometimes subrimose, the exposed flesh appearing whitish, cuticle evenly "vinaceous buff" and remaining so throughout development, in age the disc often marked with roundish more or less watery spots, margin incurved and cottony-fibrillose when young; flesh white, thick (7–8 mm. near the stipe), unchanging, odor subfarinaceous when cut, taste mild or slightly fungoid; lamellae approximate to the stipe but free, very close (120–130 almost reach the stipe), many lamellulae present, broad (1 cm.), pure white until late maturity, then dull grayish to olivaceous gray, especially along the edges; stipe 10–15 cm. long, 1–2.5 cm. thick, solid, base somewhat enlarged into an oval bulb which is rounded underneath, conspicuously longitudinally appressed-fibrillose-striate above and below the superior membranous annulus,

neither scaly nor sheathed, interior pallid, the surface somewhat darker; annulus membranous, thin, sometimes evanescent, fibrillose on both surfaces, dull pale vinaceous gray, paler than the pileus.

Spores 4–5 × 3.5–4 μ, white in mass, ellipsoid to subglobose, nonamyloid, smooth; basidia 18–30 × 4–6.5 μ, four-spored, hyaline in KOH; cheilocystidia and pleurocystidia not differentiated; gill trama of divergent hyphae, hyaline in KOH; cuticle of pileus of more or less upright subgelatinous hyphae 14–24 × 4–5 μ, the end cells attenuated to an obtuse point, more or less hyaline; pileus trama of hyaline floccose hyphae with clamp connections at the cross walls.

Habit, habitat, and distribution. — Gregarious to scattered under elm and ash in swamps; southern Michigan.

Observations. — *L. lenticularis* is the central species around which several others are grouped. It is apparently much more common in Europe than in North America, and is well described and illustrated in the European literature.

Limacella lenticularis var. **Fischeri** (Kauffman), comb. nov.

Lepiota Fischeri Kauffman, Agar. Mich., I: 630. 1918.

Illustration:
Kauffman, *op. cit.*, Vol. II, pl. CXXVII.

Pileus 4–9 cm. broad, convex-campanulate, obtuse, even, subviscid with a separable cuticle, white to pale alutaceous, flesh thick, white, and soft, taste slight, odor becoming strong on drying (like that of *Tricholoma sulfureum*), lamellae crowded, rather narrow, plane, white, free and somewhat remote, edge entire; stipe 4–10 cm. long, 4–10 mm. thick, subbulbous, striate, fibrillose, fibrous-fleshy, solid, firm, separable from the pileus, annulus large, superior, white and fragile, subpersistent, at length pendulous.

Spores subglobose to oval, 3.5–5.6 × 4.5–6.6 μ (according to Kauffman, 3–4 × 2–3 μ), with a distinct apiculus, very pale yellow in chloral hydrate–iodine solution (very few spores now present in the type); basidia 15–21 × 3.4–6.2 μ, sterigmata few, three seen on one basidium (according to Kauffman, there are usually 1–2, rarely 3–4, and they measure 5–7 μ long); neither pleurocystidia nor cheilocystidia present; gill trama compact and divergent; pileus trama homogeneous and fairly compact under a pellicle consisting of

upright more or less irregular blunt-pointed slightly differentiated hyphal tips 15–30 μ long and 4–5 μ in diameter, their gelatinous nature not readily visible when revived in KOH.

Habit, habitat, and distribution. — Gregarious on leaf mold or on the ground in low frondose woods. It has been found in Ontario, Canada, and in Michigan and Pennsylvania in the United States.

Observations. — The type, which has been examined, has very few spores. They measure 3.5–5.6 × 5.5–6.6 μ. Several additional collections identified by Kauffman were also present among his collections and were found to have the same size spores as the type. Consequently the strong odor on drying and the absence of green drops or olivaceous discolorations are left as the principal differences between var. *typica* and var. *Fischeri*. These do not appear sufficient to justify maintaining Kauffman's fungus as a distinct species, particularly in the light of the pronounced similarities of the two in all other respects. *L. solidipes* is distinguished by its strongly farinaceous odor and taste and paler colors when fresh. In the dried condition, however, all three have become about the same shade of pinkish buff.

10. **Limacella solidipes** (Peck), comb. nov.

Lepiota solidipes Peck, Bull. New York State Mus., 5: 647. 1899.
Limacella McMurphyi Murrill, Mycologia, 4: 213. 1912.

Pileus 3–7 cm. broad, broadly convex to plane, viscid when moist, white at first but gradually becoming "pale pinkish buff" (very pale alutaceous), surface subrimose in age but never fibrillose or scaly, always opaque and dull; flesh white, 5 ± mm., tapering to margin, rather firm in consistency, odor and taste strongly farinaceous, lamellae crowded, attached to the stipe by a narrow tooth or simply approximate, edges even, no color change; stipe 8–10 cm. long, 10–12 mm. thick, equal, solid, firm, base sometimes slightly enlarged, surface glabrous above the annulus and beaded with hyaline drops, sparsely fibrillose below with scattered innate fibrils, never scaly; annulus superior, white and persistent, ample and pendulous.

Spores subglobose to globose, 4 × 5 μ or 4–5 μ in diameter, with a definite apiculus, very slightly yellow in iodine; basidia 19–32 × 4.5–6 μ, four-spored; neither pleurocystidia nor cheilocystidia differentiated; gill trama divergent from a central strand of fairly

large cells, subhymenium of small compactly arranged cells, hyaline in KOH; pileus trama with a distinctly differentiated cuticle of upright septate hyphae with distinctive rather blunt-pointed end cells, which taper somewhat like the filaments of Rivularia, the walls somewhat gelatinous; gill trama floccose-filamentous, becoming more compact toward the hymenium, cells about equal in width (3–8 μ in diameter), hyaline in KOH, clamp connections present.

Habitat and distribution. — Growing on humus under alder on swampy ground or among leaves under redwoods; New York, California, and Washington.

Observations. — *L. solidipes* is very closely related to *L. lenticularis* but can readily be distinguished by its white pileus, at least on young fresh specimens, and by the strong farinaceous odor and taste. Although the stipe above the annulus was beaded with drops of moisture, there is no indication that these ever assume olivaceous tints. *L. McMurphyi*, which also has a farinaceous odor and taste, is tentatively referred here, since no distinctions between the two are evident from the information available. As yet the type of the latter has not been sectioned to verify its position in this genus. Dried specimens of *L. solidipes* and *L. lenticularis* have much the same appearance.

11. *Limacella glioderma* (Fr.) Earle, Bull. New York Bot. Gard., 5 : 447. 1909.

Agaricus (*Lepiota*) *gliodermus* Fries, Monogr. Hymen., 1 : 31. 1857.
Lepiota glioderma Gillet, Les Hyménomycètes, p. 73. 1874.
Armillaria glioderma Quélet, Champ. Jura et Vosges, Suppl. 3 (113) : 541. 1875.
Gyrophila glioderma Quélet, Enchir. Fung., p. 9. 1886.
Amanitella glioderma Maire, Ann. Mycol., 11 : 337. 1913.
Amanita (subg. *Limacella*) *glioderma* Gilbert, Le genre Amanita Persoon, p. 167. 1918.
Melanoleuca subpessundata Murrill, Mycologia, 5 : 222. 1913.
Tricholoma subpessundatum Murrill, Mycologia, 5 : 223. 1913.
Limacella subpessundata Singer, Lloydia, 5 : 132. 1942.
Melanoleuca subvelata Murrill, Mycologia, 5 : 222. 1913.
Tricholoma subvelatum Murrill, Mycologia, 5 : 223. 1913.
Armillaria graveolens Murrill, Mycologia, 35 : 422. 1943.

Illustrations:
Plate I.
Fries, Icon. Hymen., pl. 15, no. 1.

Pileus 3–8 cm. broad, obtuse when young, the margin incurved slightly, becoming nearly plane with a very low broad umbo, in age

the margin may be broadly recurved, surface with a thin coat of gluten when young, becoming merely viscid and with a dry granulose appearance under a lens, later breaking up into crustose patches which show the pale flesh beneath, cuticle "carob brown" to "chestnut brown" when young, becoming paler and near "onion skin pink" on the margin and "cameo brown" near the darker disc (dark reddish or chestnut brown fading to pale vinaceous brown); flesh thick on the disc, thin elsewhere, very soft and fragile, whitish but tinged pale vinaceous, odor and taste very strongly farinaceous; lamellae close but distinct, approximate to the stipe or attached by a tooth, 35–37 just about reach the stipe, 1–2 tiers of lamellulae, broad (5–10 mm.), becoming ventricose, whitish at first, becoming "pale pinkish buff," edges even or slightly fimbriate; stipe 5–9 cm. long, 5–10 mm. thick, solid or hollow, equal or tapering slightly above, surface pallid above and glabrous to appressed-silky, with "fawn color" to "light vinaceous cinnamon" zones of fibrils below formed from the veil, no membranous annulus, dry over all or viscid when gluten from the cap has dropped on it.

Spores globose or subglobose, 3–4 μ in diameter or occasionally up to 5 μ, not amyloid or old spores sometimes pseudoamyloid; basidia four-spored, often projecting when sporulating, 16–22 × 5–7 μ; pleurocystidia and cheilocystidia not differentiated; gill trama clearly divergent from a central strand, subhymenium parenchymatous, clamp connections present; cuticle of pileus gelatinous, the cells somewhat interwoven and more or less erect (as seen in liquid mounts of sections), 2–4.5 μ in diameter and about 30 μ long, tapering to a point; pileus trama floccose and loosely organized.

Habit, habitat, and distribution. — Single, scattered to gregarious, on rich humus under hardwoods or conifers. In North America it is known from Nova Scotia and Ontario in Canada, and from Florida, Maryland, New York, Michigan, Washington, and Oregon in the United States. It is one of the two relatively common species of Limacella. It usually fruits during the late summer and fall.

Observations. — Singer (1942) first recognized that *Tricholoma subvelatum* and *T. subpessundatum* belong in Limacella and are conspecific. I have collected the fungus in considerable abundance along the west coast of the United States, but have been able to distinguish only the one species. Its colors vary much in intensity, but from the information available there appear to be no distinct color

forms and, as a result of a study of Murrill's types, no characters have been found to separate his species from *L. glioderma*. The colors of the dried carpophores of *Armillaria graveolens* are slightly more brownish than is typical for *L. glioderma*. This difference and Murrill's description of the color of the fresh cap as isabelline may indicate the presence of a distinct southern form in our flora. The point, however, needs careful study of more material than is available at present. In all the fresh material I have studied the odor and taste were very pronounced and constant, and no forms with a mild taste were collected. The fruiting bodies photographed were rather large. Plate I shows the cuticle pulling back from the margin of the pileus in the cap at the left. This causes old caps to have a ragged appearance.

12. *Limacella delicata* (Fries) Earle, Bull. New York Bot. Gard., 5 : 447. 1909.

Agaricus (*Lepiota*) *delicatus* Fries, Syst. Mycol., I : 23. 1821.
Lepiota delicata Gillet, Les Hyménomycètes, p. 73. 1874.
Armillaria delicata Boudier, Icon. Mycol., I : 12. 1905.
Amanita (subg. *Limacella*) *delicata* Gilbert, Le genre Amanita Persoon, p. 168. 1918.

Illustrations:
Boudier, Icon. Mycol., Vol. I, pl. 23.
Fries, Icon. Sel. Hymen., pl. 15, no. 2.

Pileus 2–8.4 cm. broad, campanulate, convex or obtuse, sometimes with a very large obtuse umbo, the margin at times somewhat elevated and finally wavy, opaque, pale to rather dark brownish red, the margin incarnate brownish, glabrous, cuticle subviscid when wet, then becoming dull and unpolished; flesh thick on the umbo, thin at the margin, white or more or less hyaline, but mostly concolorous with the cuticle near the surface, odor slightly of green wood, not at all farinaceous; lamellae white or milk white, not very crowded, 44–48 reach the stipe, 1–3 tiers of lamellulae, more or less ventricose, narrowly adnexed, then free or remaining attached by cobwebby filaments, lamellulae not truncate toward the stipe; stipe 2.5–5 cm. long, 3–6 mm. thick, subequal or slightly attenuated downward, evidently tinted rosy-flesh color, base more or less whitish, annulus absent or present as woolly fibrillous zones or floccules scattered over the lower portion, solid or stuffed, flesh soft, brittle, cream color.

Spores round, 4–5 μ in diameter, smooth, with an abrupt apiculus, white in mass; basidia 25–30 × 5.5–6.2 μ; gill edges provided with numerous claviform hairs 8–9 μ, with clamp connections; gill trama bilateral, hyphae diverging regularly and appearing more or less cellular between the central strand and the subhymenium; cuticle of pileus of erect gelatinous hyphae with clamp connections, elongated, 4–6 μ in diameter, mostly colorless but some with oily yellow contents, the brown pigment located in the hypoderm in the form of irregular plates incrusting the hyphae.

Distribution. — This species is at present not definitely known to occur in North America.

Observations. — The description is translated and adopted from Kühner (1936). Small fruiting bodies answering the description given above in nearly all respects are not uncommon among the collections of Kauffman and A. H. Smith in the University of Michigan Herbarium, but no record of their taste is available. Consequently the presence of *L. delicata* in North America has not been established, although I suspect that it occurs here. It was reported by some of the early investigators. Aside from the small size, the lack of a farinaceous taste is about the only character which would distinguish *L. delicata* from *L. glioderma*. Kühner (1936) has suggested that they may be merely varieties of a single species.

Excluded and Doubtful Species

Lepiota irrorata Quélet–Rea. — A true Lepiota (Kühner, 1936).

Lepiota rubida Kauffman. — Placed in the Viscidae of Lepiota by Kauffman, who stated that it has regular gill trama, a fact confirmed by an examination of his material. It is, therefore, a true Lepiota.

Limacella albissima Murrill. — This is *L. pulcherrima* Graff, and is a true Lepiota with regular gill trama.

Limacella bentista (Morgan) Murrill. — Tentatively excluded because of the large spores. A study of the gill trama is necessary to determine exactly where this species should be placed.

Limacella fulvodisca (Peck) Murrill. — A study of the type shows that this has regular gill trama and is, therefore, a true Lepiota.

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PLATE 1

Limacella glioderma (Fries) Earle. × 1

A PERFORATING SPECIES OF ECTOCHAETE (HUBER) WILLE FROM THE GALÁPAGOS ISLANDS

FRANCESCA THIVY

AN UNDESCRIBED alga appears among the perforating Chlorophyceae found in dead shells and worn coral specimens in the collections of the Hancock Galápagos Expedition of 1934. It forms a rich growth in the outer layers of a large shell. In its sporangia and individual filaments it resembles the perforating alga *Phaeophila Engleri* Reinke, but it has a distinguishing habit and is also different in the number of nuclei to a cell. Staining with acetocarmine immediately after decalcification with 2 per cent glacial acetic acid showed uninucleate cells (Pl. I, Figs. 18–20). This result could usually be seen about thirty-six hours after staining. It was found, by the use of the same stain, that *P. Engleri* Reinke and *P. dendroides* (Crouan) Batters have predominantly multinucleate cells. This character proves decisively that the alga is a species of Ectochaete (Huber) Wille, the concept of which, like that of the closely allied genus Entocladia Reinke (Kylin, 1935, pp. 197, 201), would now include the perforating habit of growth.

Ectochaete (Huber) Wille, 1909

(Plate I)

Möbius, 1891, p. 1292, pl. XIV, figs. 1–10; Huber, 1892a, p. 331, fig. 5; 1892b, pp. 319–326, pl. XV, figs. 1–17; Batters, 1902, p. 14; Wille, 1909, p. 79; Heering, 1914, pp. 97–98; Børgesen, 1920, pp. 418–419, fig. 400; Oltmanns, 1922, I: 299–300; Printz, 1927, p. 194; Hamel, 1930, p. 28; Newton, 1931, p. 62; Feldmann, 1937, p. 181; Taylor, 1942, pp. 15 16; Thivy, 1942, pp. 97–109; 1943, pp. 250–258.

A marine or fresh-water genus, endophytic between the wall layers or in the slime of larger algae, or perforating in shells; thalli consisting of discs of radiating or congested, free or partly fused filaments; branching lateral, at times subdichotomous; cells cylindrical to round, setigerous, uninucleate with a parietal platelike, rarely

perforate, chloroplast, containing starch granules and 1–8 pyrenoids; seta tubular, straight, usually occurring singly, without a basal septum, or occasionally with the lumen at the base nearly obliterated by a simple increase in thickness of the wall or by an annular thickening, or at times partitioned by a secondary septum; plants reproducing by biflagellate zoospores and gametes, each with a chloroplast, a pyrenoid, and an eyespot; germination direct, taking place either by the production of a germination tube from the anterior end of the zoospore, in a line with its long axis, or without it, but by the formation of filaments in one or more directions more or less perpendicular to the long axis of the zoospore.

Ectochaete perforans, sp. nov. — Plant forming a dense growth in the prismatic layer of dead shells, composed of closely packed, free, laterally branched filaments, with the basal septum of a branch usually placed a little above the branch insertion; cells cylindrical, short to very long, uninucleate, with a platelike parietal, homogeneous to granular chloroplast, containing starch and frequently one or, rarely, 2–3 pyrenoids, often setigerous or sometimes with a small incrassate knob on the wall; intercalary cells usually 7–20 μ in diameter, the length 1.3–4.0 times the diameter, up to 43 μ, often with a lateral lobe, here and there constricted-rhizoidal when the cell is 3 μ in diameter; terminal cells 7–13 μ in diameter, length 3–9 times the diameter, from 20 to 95 μ; seta straight, continuous with the lumen of the cell but at times with a basal secondary septum or annular thickening of the wall, single or, extremely rarely, two to a cell, 2.0–3.8 μ in diameter, the length reaching 50 μ; sporangia as a rule intercalary, 7–28 μ in diameter, the length 1.5–2.5 times the diameter, from 17 to 38 μ, with about 12 zoospores of 3.5–8.0 μ diameter showing a nucleus, a chloroplast, a pyrenoid, and an eyespot; emission tube 3.5–5.0 μ in diameter, up to half as wide as the sporangium, usually slightly narrower than the diameter of the zoospores, in length mostly 1–3 times the height of the sporangium but up to 29 μ, very rarely absent; aplanosporangia rare, with aplanospores about 8 μ in diameter.

Galápagos Islands: Isabela I., in dead shells in tide pools at Cartago Bay, *W. R. Taylor 34-352E*, January 25, 1934.

The shell is conical, 10 cm. long and 6.5 cm. in diameter at the wider end. The alga described here is embedded to some depth, chiefly in the outer face of the shell, along with *Hyella caespitosa*

B. & F., whereas in the same shell *Pilinia maritima* (Kjellm.) Rosenv., forma nova *pacifica* (inedit.), occurs in the outermost part.

Ectochaete perforans. — Thallus in stratum prismaticum concharum perforans, e filamentis ramosis, confertis, non coniunctis compositus; cellulis uninucleatis, pyrenoideis plerumque uno, infrequenter 2–3, praeditis, saepe unam setam (vel rarissime duas) gerentibus; setis 2.0–3.8 μ crassitudine, rectis, non basi septatis sed interdum aut ad basim incrassatione parietali annuliformi aut septo basali secundario instructis; cellulis intercalaribus 7–20 μ crassis, 1.3–4-plo longioribus quam crassioribus, longitudine minus quam 43 μ, passim radiciformibus, angustis, circa 3 μ crassitudine; cellulis terminalibus 7–13 μ crassitudine, 3–9-plo longioribus quam crassioribus sed inter 20 et 95 μ; sporangiis plerumque intercalaribus 7–28 μ crassis, 17–38 μ longis, circa 12 zoosporas includentibus, ostiolo tubuliformi 3.5–5.0 μ crasso, 3.5–29 μ longo. Specimina typica legit W. R. Taylor, no. 34–352E, in loco dicto Cartago Bay, I. Isabela, in Insulis Galapagorum.

As found in the decalcified material, the chloroplast was generally homogeneous (Figs. 1, 3, especially) and extraordinarily thin and translucent, but at times granular, yet still thin; in either condition starch was present. A fraction of the cells had pyrenoids, which became visible only on staining. In a large number of the setae a secondary septum was seen (Figs. 8–9), and a preceding step in its development was observed in the clear plasma membrane, which occurred frequently across the opening of the seta (Fig. 7). In setae remaining open at the base a plasma membrane is not visible (Figs. 1, 5, especially). In this genus the seta at first has a cytoplasmic lining continuous with that of the cell (Huber, 1892a, p. 331, fig. 5; 1892b, p. 321, pl. XV, fig. 3), later it practically disappears in the seta, but no visible plasma membrane or wall has been noticed across the base of the seta in the other species. Very rarely the sporangium either has a papillate process (Fig. 17) or does not develop an emission tube, an opening being formed directly in the wall (Fig. 17).

The outer branches, which are crowded and are either unicellular and very long or two- to four-celled, each with a very long terminal cell (Figs. 1–2, 19–20), are distinctive of the species. By comparison with that characterizing the other species, in *Ectochaete perforans* the ratio of the diameter of the emission tube to that of the sporangium is, on the whole, smaller (Figs. 11–16).

In the genus reproduction by aplanospores (Fig. 21) has been observed only in *Ectochaete perforans*. *Phaeophila Engleri* (Thivy, 1943, pl. I, fig. 8), which is a perforating form, has been found to have these spores. This suggests that this method of asexual multiplication is an adaptation to the frequently deep penetration of these algae. The scattered attenuate rhizoidal intercalary cells (Fig. 10) no doubt serve the purpose of boring into the hard layers of shells.

A key to *E. leptochaete* (Huber) Wille, *E. Taylori* Thivy, and *E. endophytum* (Möbius) Wille was previously given (Thivy, 1942, p. 98), but no specimens of *E. leptochaete* had been seen by the writer till the species was found at Woods Hole, Massachusetts, in the summer of 1942. With a better knowledge of this species the presence of a few setae, which was considered characteristic of it, is found to be only a variable feature, for in some discs many appear. A closer study of the marine species has shown, besides, that *Endoderma vagans* Børgesen is an Ectochaete because it produces setae and that the genus possesses considerable plasticity of habit, and of seta (Figs. 6, 8; Thivy, 1943, pp. 256–258) and sporangium structure, grows in varied substrata, and has a wide distribution. Like *Acrochaete repens* Prings. and *P. Engleri*, one among the endophytic species, and the perforating species of Ectochaete establish contact with the water by means of incrassate processes on their cell walls (Figs. 3–4), as well as by setae. The increasing interest of botanists in the genus justifies the provision of a fuller key to its species.

KEY TO THE SPECIES OF ECTOCHAETE

1. Marine 2
1. Fresh water 5

2. Endophytic in cell wall or slime of larger algae; emission tube wide, its diameter one to several times that of zoospores, 0.5–1.0 times diameter of sporangium 3
2. Perforating in shells; emission tube narrow, usually of slightly smaller diameter than that of zoospores, up to 0.5 times the diameter of sporangium, length up to 3 times the diameter of sporangium; filaments free, in various planes, crowded; cells usually 7–20 μ in diameter, length 1.3–4.0 times the diameter, within 43 μ; terminal cells 7–13 μ in diameter, length 3–9 times the diameter, from 20 to 95 μ; setae 2.0–3.8 μ in diameter, seen with difficulty; pyrenoids 1–3; sporangia 7–28 μ in diameter, length 1.5–2.5 times the diameter, 17–38 μ..... *E. perforans*

3. Endophytic in the outer cell walls of the host, thallus disclike, filaments predominantly in one plane; setae 1.0–1.5 μ in diameter and inconspicuous; cells usually 5–15 μ in diameter 4

3. Endophytic in slime binding the cortical filaments of host; thallus matted, punctiform; filaments in various planes, mostly free; setae 3–4 μ in diameter, conspicuous; cells usually 8–18 μ in diameter, length usually 1–3 times the diameter, up to 33 μ; pyrenoids 1–8; sporangia 9–13 μ in diameter, length 1.0–3.5 times the diameter, up to 39 μ; emission tube in length 0.3–5.0 times the diameter of the sporangium ..... *E. Taylori*

4. Discs distinctly pseudoparenchymatous, outer branches not widely spreading; central cells 5–15 μ in diameter, length 1.0–1.5 times the diameter, up to 15 μ; outer cells usually longer, 4–5 μ in diameter, length 2–4 times the diameter, up to 18 μ; cells without incrassate process on wall; setae 1.0–1.5 μ in diameter, seen with difficulty, base not incrassate-conical; pyrenoids 1–4; sporangia 5–12 μ in diameter, roundish; length of emission neck 0.3–0.5 times the diameter of the sporangium, without incrassate wall ..... *E. leptochaete*

4. Disc very slightly or not pseudoparenchymatous, outer branches widely spreading; central cells usually 5–10 μ in diameter, length 1–4 times the diameter, up to 30 μ (at times said to reach 13 μ in diameter); outer cells usually much longer, 1–5 μ in diameter, length 5–17 times the diameter, up to 80 μ; cells often with incrassate process on wall; setae about 1 μ in diameter, seen with very great difficulty, base incrassate-conical; pyrenoids 1–7; sporangium usually 9–11 μ in diameter, length about 1.5 times the diameter; emission neck as in previous species, but usually with incrassate wall ..... *E. vagans*

5. Endophytic in walls of filamentous green algae; thallus disclike, pseudoparenchymatous, later breaking through host wall and forming pulvinate mass of fused spherical cells; cells 8–20 μ in diameter, length 1–5 times the diameter; setae firm, refringent; sporangia roundish; length of emission neck about equal to diameter of sporangium .... *E. endophytum*

The writer is greatly indebted to Professor William R. Taylor, of the University of Michigan, for the opportunity of studying the perforating Chlorophyceae represented in the collections made by him as botanist of the Hancock Expedition of 1934.

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PLATE I

EXPLANATION OF PLATE I

Ectochaete perforans, sp. nov.

FIG. 1. Outer filament showing the basal septa of branches, two setigerous cells at *a* and *b*, and terminal cells. × 761

FIG. 2. Filament with a very long terminal cell. × 352

FIG. 3. Filament showing two cells with sinuous walls and one with an incrassate knob on wall. × 352

FIG. 4. Cell with a process capped by an incrassate knob on wall. × 440

FIG. 5. Filament showing three setae without basal septa. × 352

FIG. 6. Two setigerous cells, one with two setae. × 385

FIG. 7. Cell showing two setae with clear plasma membranes across their bases. × 761

FIG. 8. Filament showing a seta with a secondary basal septum at *a*, and another with a basal annular thickening of the wall at *b*. × 761

FIG. 9. Filament showing a lobed cell and two setigerous cells at *a* and *b*, the seta at *a* having a secondary basal septum. × 352

FIG. 10. Filament showing an intercalary, constricted, rhizoidal cell. × 352

FIG. 11. Sporangium showing a nucleus in all but one of the zoospores, stained with acetocarmine. × 761

FIG. 12. Lobed sporangial cell. × 352

FIG. 13. Sporangium; zoospores about 3.5 μ in diameter, emission tube 4.7 μ in diameter. × 761

FIG. 14. Filament with two sporangia; zoospores 4.7–5.8 μ in diameter, emission tube 4.7 μ in diameter. × 761

FIG. 15. Filament with two sporangia, the one at *a* empty; in the other three zoospores showing one eyespot each and one a pyrenoid; zoospores 5.9–8.2 μ in diameter, emission tube 3.5 μ in diameter. × 352

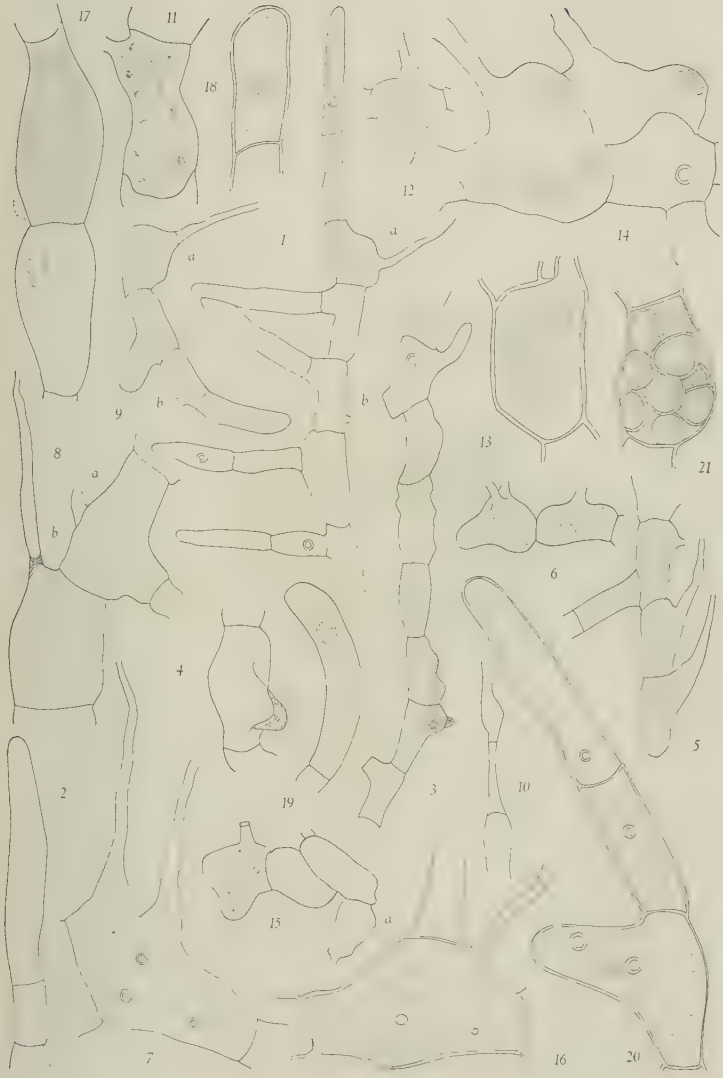
FIG. 16. Sporangial cell with a emission tube 3 μ in diameter and a wider branch cell; divisions of protoplast 2.3–6.0 μ in diameter, the pyrenoid seen in two of them. × 761

FIG. 17. Two sporangia, the empty lower one showing an opening directly in the wall, the upper with a papillate process, shown by broken line. × 761

FIGS. 18–19. Two vegetative cells showing the single nucleus, stained with acetocarmine. × 761

FIG. 20. Filament showing terminal cell and pyrenoids; one cell showing nucleus, stained with acetocarmine. × 761

FIG. 21. Aplanosporangium with aplanospores surrounded by cell walls. × 761



Ectochaete perforans, sp. nov.

NEW AND UNRECORDED MARINE ALGAE OF HONG KONG*

CHENG KWEI TSENG

ALTHOUGH the marine algae of Hong Kong have been studied by various phycologists for over a hundred years, the number of species reported is pitifully small. In 1940 the writer published a list of seventy-eight species definitely known to be represented in this region. In subsequent papers (Tseng 1941, 1942, 1943 a–b, 1944 a–c) he has added thirty species to the floristic list of Hong Kong, including thirteen newly described. Further studies have revealed the occurrence of many species that have not previously been reported from this region, some of which are believed to be new. The present paper is a report of the studies on several of these marine plants.

1. *Acrochaetium crassipes* (Børg.) Børg.

Børgesen, Marine Algae of the Danish West Indies, II, i, 1915, p. 20, fig. 11; *idem*, Some Indian Rhodophyceae, 1931, p. 2, fig. 1.
Chantransia crassipes Børg., West Indian Florideae, I, 1909, p. 1.

Small epiphytic algae up to about 70 μ high. Basal cell shortly subcylindrical or barrel-shaped, with a rather thick wall about 10 μ in diameter, fastening to the surface of the host by a rather thick layer of cementing substance. Erect filaments often unilaterally branched, more or less curved and decumbent, largest near the base, tapering toward the summit, where the cells are only about 3 μ in diameter. Hairs seldom present. Cells about as long as broad, constricted at the transverse walls, each with a single axial, stellate chromatophore having a central pyrenoid. Monospores oval to obovate, about 5 μ broad and 6 to 7 μ long. Sexual organs unknown.

Habitat. — On Polysiphonia from Panglongwan, Port Shelter, in March (*Taam A62a*).

Distribution. — St. Thomas, West Indies (type locality), and Dwarka, India.

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2. Acrochaetium arcuatum (Drew), comb. nov.

(Plate I, Figure 1)

Rhodochorton arcuatum Drew, A Revision of the Genera Chantransia . . ., 1928, p. 165, pl. 37, figs. 1–3.

Small epiphytic algae up to about 120 μ high. Basal cell globular or subglobular, about 10 to 12 μ in diameter, almost twice as large as the other cells above. Erect filaments two or three from the same basal cell, sometimes four, unilaterally or alternately branched (Pl. I, Fig. 1). Cells more or less barrel-shaped, 5 to 10 μ in diameter, one to two times as long, each with a single stellate chromatophore having a central pyrenoid. Monosporangia oval, terminal, or lateral, 6 to 8 μ broad, 8 to 12 μ long. Spermatangia not found; carpogonia still unknown.

Habitat. — On Chaetomorpha from Shek-O, Hong Kong I., in December (*Tseng 258a; Taam A13a*).

Distribution. — Moss Beach, San Mateo County, California (type locality); from Cape Flattery, Washington, southward to central California.

3. *Acrochaetium robustum* Børg.

(Plate I, Figures 2–4)

Børgesen, Marine Algae of the Danish West Indies, II, i, 1915, p. 40, figs. 38–40; II, vi, 1920, p. 449, fig. 418.

Rhodochorton robustum (Børg.) Nakamura, Species of *Rhodochorton* from Japan, I, 1941, p. 284, figs. 10–13.

Acrochaetium sargassicolum Børgesen, Some Indian Rhodophyceae, II, 1932, p. 115, figs. 3–5.

Bushy epiphytic algae up to 2 mm. or more high. Basal cell subcylindrical-oblong, conspicuously constricted in the middle, the lower half being embedded in the host tissue, about 12 to 15 μ broad, 15 to 28 μ long (Pl. I, Fig. 2). Erect filaments solitary, sometimes two, from the same basal cell, profusely, irregularly, laterally branched, with a greater tendency to unilaterality (Pl. I, Fig. 3). Cells subcylindrical, 6 to 11 μ broad, larger below, smaller above, two to three times as long as broad below, up to as much as four to six times longer than the breadth near the summit. Chromatophore parietal, with a large protruding pyrenoid. Monosporangia ellipsoidal, sessile or pedicellate, lateral or terminal, about 11 to 12 μ broad, 17 to 20 μ long (Pl. I, Fig. 3). A tetrasporangium

found only once, sessile and lateral on a branchlet (Pl. I, Fig. 4). Spermatia and carpogonia not found.

Habitat. — Abundant on Sargassum, covering almost the entire plant body, from Cape d'Aguilar (*Tseng 2690*) and Stanley Beach (*Taam A68*), both on Hong Kong I., in March.

Distribution. — Bombay, India (type locality).

4. *Dermonema gracilis* (Mart.) Schmitz

(Plate I, Figures 5–6)

Schmitz, *in* Heydrich, Beiträge . . . Algenflora von Ost-Asien, 1894, p. 289; Weber-van Bosse, Liste des algues du Siboga, II, 1921, p. 204; Børgesen, Marine Algae of Ceylon, 1936, p. 80; *idem*, South Indian Marine Algae, 1937, p. 320.

Gymnophloea gracilis Martens, Die Tange, 1866, p. 146; Kützing, Tabulae phycologicae, XVII, 1867, pl. 1.

Dermonema dichotomum Harv., Algae from Ceylon, No. 93 (*nomen nudum*); Schmitz und Hauptfleisch, Helminthocladiaceae, 1897, p. 335, fig. 205.

Frond caespitose, attached by large discoid holdfast, profusely dichotomously branched in all directions, up to 6 cm. high. Branches terete or subcompressed near the base, about 2 mm. broad. Axial filaments about 5 to 7 μ in diameter. Assimilatory filaments once or twice dichotomously branched, with a large basal cell about 15 to 20 μ in diameter. Peripheral cells obovate, much swollen at the apices, about 10 to 16 μ in diameter at the broadest portion. The two or three cells below them much smaller, about 4 to 6 μ in diameter. Dioecious. Spermatangia in groups of two to four at the tips of the spermatangial cells, which form whorls around the narrow cells just below the large terminal cells (Pl. I, Fig. 5). Carpogonial filament 3-celled, more or less curved, although sometimes perfectly straight, lateral on the basal cell of the assimilatory filaments, about 10 to 20 μ broad (Pl. I, Fig. 6). Cystocarps not found. Color yellowish to dark purple.

Habitat. — Caespitose on exposed rocks in the littoral region, Hong Kong I.; Shek-O, from December (*Taam A11*) to March (*Tseng 654, 2659*) and Big Wave Bay, in April (*Tseng 2706*); Pang-longwan, Port Shelter, in March (*Taam A61*); and Lemma I., in May (*Taam A118*).

Distribution. — Calle, Ceylon (type locality); Formosa; New Guinea and Cape Comorin, South India.

This species is very common in the Hong Kong region in places

exposed to strong surf action. It is a spring annual, occurring in the period from December to May, when it begins to turn yellowish and soon dies off. It entirely disappears at the end of May. The materials collected show good spermatangia and carpogonia, but the writer never had any success in finding the peculiar development of the cystocarps described and illustrated by Schmitz, *op. cit.*

5. *Fosliella farinosa* (Lamx.) Howe

Howe, Bahama Algae, 1920, p. 587; Taylor, Marine Algae of Northeastern . . . North America, p. 270.

Melobesia farinosa Lamouroux, Histoire des polypiers corallingènes flexibles, 1816, p. 315, pl. 12, fig. 3; Hauck, Meeresalgen, 1885, p. 263, fig. 107; Lemoine, *in* Børgesen, Marine Algae of the Danish West Indies, II, 1920, p. 170, fig. 165.

Frond forming whitish fragile crusts on various algae, 2 to 5 mm. in diameter or more. Vegetative cells subrectangular in surface view, 8 to 14 μ broad and 16 to 28 μ long. Colorless swollen cells or "heterocysts" present, 1.5 to 2.0 or more times larger than the vegetative ones. Sporangial conceptacles hemispherical or conical, scattered or somewhat crowded, 140 to 250 μ in diameter, with tetrasporangia 30 to 50 μ in diameter and 50 to 90 μ long. Cystocarpic conceptacles similar in size and shape, but the spermatangial ones much smaller, being only about 60 to 80 μ in diameter.

Habitat. — Epiphytic on Laurencia from Cape d'Aguilar, Hong Kong I., in March (*Tseng 2691a*); on *Caulerpa*, washed ashore, Clearwater Bay, Port Shelter, in February (*Taam A33d*).

Distribution. — Probably cosmopolitan.

6. *Fosliella Lejolisii* (Rosan.) Howe

Howe, Bahama Algae, 1920, p. 588; Taylor, Marine Algae of Northeastern . . . North America, 1937, p. 270, pl. 36, figs. 6–8.

Melobesia Lejolisii Rosanoff, Recherches, 1866, p. 62, pl. 1, figs. 1–13; Hauck, Meeresalgen, 1885, p. 264, fig. 108.

Frond forming delicate, dull pink or pale reddish thin crust up to about 2 mm. broad. Vegetative cells about 6 to 10 μ broad in surface view, and somewhat longer. Heterocysts absent. Conceptacles and sporangia similar to those of the preceding species in shape and size.

Habitat. — Epiphytic on Herposiphonia, intermingled with Falkenbergia, from Clearwater Bay, Port Shelter, in May (*Tseng 2803b*).

Distribution. — Cherbourg, France (type locality); probably cosmopolitan.

7. *Gymnogongrus divaricatus* Holm.

Holmes, New Marine Algae from Japan, 1895, p. 255, pl. 7, fig. 3 a–b; Okamura, Icones of Japanese Algae, VII, ii. 1933, p. 16, pl. 310, figs. 1–5.

Frond regularly divaricately, dichotomously, flabellately branched, up to 3 cm. high. Branches linear-compressed, about 1 mm. broad. Segments of approximately equal length and breadth throughout, slightly cuneate at the base, bifid at the apices. Proliferation common on the lower branches. Plants rather cartilaginous and purplish red.

Habitat. — Tufted on sand-covered rocks and in rock pools in the littoral region in April: Stanley Beach, Hong Kong I. (*Tseng 283*) and Putoi I. (*Tseng 2742*).

Distribution. — Province Kii, Shimoda, Misaki, and Province Totomi, Japan.

8. *Gracilaria Blodgettii* Harv.

Harvey, Nereis Boreali-Americana, II, 1853, p. 111; Taylor, Marine Algae of Florida, 1928, p. 151, pl. 23, fig. 9, pl. 33, fig. 6; Weber–van Bosse, Liste des algues du Siboga, IV, 1928, p. 430, fig. 174.

Frond richly branched, arising from a discoid holdfast up to 10 cm. high. Branching lateral, very irregular, with longer and shorter branches intermingled. Branches about 1 mm. in diameter, abruptly constricted at the base and quickly tapering to fine points at the apices. Cystocarps numerous, conical, scattered over the frond. Plants firmly succulent and yellowish to light brownish red.

Habitat. — On rocks in the lower littoral region, Clearwater Bay, Port Shelter, in May (*Tseng 2802*).

Distribution. — Key West, Florida (type locality) and the West Indies; Kei I.; Java.

9. *Wurdemannia miniata* (Drap.) Feldm. et Hamel

Feldmann et Hamel, Observations sur quelques Gelidiacées, 1934, p. 17, figs. 9–11; *idem*, Floridées de France, VII, 1936, p. 260, figs. 34–36.

Gigartina miniata (Drap.) Lamouroux, Essai, 1813, p. 137 (*nomen nudum*).

Fucus miniatus Draparnaud, Ined., De Candolle, Flore français, V, 1815, p. 6.

Gelidium miniatum Kützing, Species algarum, 1849, p. 767; *idem*, Tabulae phycologicae, XVIII, 1868, pl. 58, figs. c–h.

Wurdemannia setacea Harvey, Nereis Boreali-Americana, II, 1853, p. 246; Kützing, Tabulae phycologicae, 1869, pl. 26; Børgesen, Marine Algae of

the Danish West Indies, II, 1920, p. 368, figs. 360–361; *idem*, Marine Algae from the Canary Islands, II, ii, 1929, p. 77, fig. 28; Taylor, Marine Algae of Florida, 1928, p. 145, pl. 20, figs. 9–10.

Distribution. — Vicinity of Montpellier (type locality), Port-Vendres, Algeria, both of the Mediterranean; Florida and the West Indies.

Var. *planicaulis* Taylor, Marine Algae from Haiti, 1943, p. 158.

Frond with a rhizomatous part, from which arise the erect branches to about 7 cm. high. The branching rather sparse, irregularly lateral and subpinnate. Basal filaments cylindrical. Branches of the erect portions distinctly compressed, reaching a breadth of 0.7 mm. Materials all sterile.

Habitat. — On sand-covered rocks in the littoral region, Big Wave Bay, Hong Kong I., in June (*Tseng 2854*).

The Hong Kong plant is in exact accord with the Haitian form recently described.

10. *Ceramium byssoideum* Harv.

Harvey, Nereis Boreali-Americana, II, 1853, p. 218; Howe, Bermuda Algae, 1918, p. 531; Weber-van Bosse, Liste des algues du Siboga, III, 1923, p. 330.

C. transversale Collins & Hervey, Algae of Bermuda, 1917, p. 145, pl. 5, figs. 29–31; Børgesen, Marine Algae of the Danish West Indies, II, 1920, p. 243, fig. 233; *idem*, Marine Algae . . . from Beata Island, 1924, p. 27, fig. 9; *idem*, South Indian Marine Algal Flora, III, 1938, p. 229.

Frond minute, epiphytic on various plants. Creeping filaments 45 to 75 μ in diameter, with cells generally about two to five times the diameter in length, cylindrical or slightly constricted at the nodes. Erect branches with somewhat shorter cells. The filament repeatedly dichotomously branched. Cortical cells limited to the nodes, characteristically transversely placed, with their long axes perpendicular to that of the filament. Tetrasporangia about 60 μ in diameter, borne singly, rarely in twos, at a node, nearly free from the cortication.

Habitat. — On Laurencia in March (*Taam A72a*) and on Gelidium in July (*Tseng 2857c*), both from Shek-O, Hong Kong I.

Distribution. — Key West, Florida (type locality); widely distributed in warmer temperate and tropical seas.

11. *Ceramium crassum* Okam.

Okamura, Icones of Japanese Algae, VI, iv, 1930, p. 26, pl. 269.

Frond epiphytic on larger algae. Filament divaricately dichotomously branched, up to 8 cm. high, 0.7 mm. in diameter below,

gradually attenuated to about 90 μ in diameter above. Apices lightly or strongly forcipate. Cortication occurring evenly throughout, rather thick, composed of four to five layers of cells, which gradually become smaller outward. Segments sometimes abundantly furnished with secund or irregularly disposed, short proliferous branchlets, often quite naked and devoid of such proliferations. Cystocarps pedicellate and involucrate, fertile branchlets proliferating from the segments secundly or irregularly. Tetrasporangia about 60 μ in diameter, immersed in the cortex and scattered over the surfaces of the branchlets.

Habitat. — On Cystophyllum, washed ashore, Shek-O, in December (*Tseng 2595*) and January (*Taam A25*).

Distribution. — Tyoshi, Enoshima, Japan (type locality).

This is the southern substitute for the northern *Ceramium rubrum*, with which it is closely related; the chief difference lies in its having a much thicker cortex.

12. *Caloglossa ogasawaraensis* Okam.

(Plate I, Figure 7)

Okamura, Algae from Ogasawara-jima, 1897, p. 13, figs. A–D; *idem*, Icones of Japanese Algae, I, viii, 1908, p. 183, pl. 37, figs. 1–11; Post, Notizen, 1936, p. 60.

C. zanzibariensis Goebel, Süsswasserfloridee aus Ostafrika, 1898, p. 65, figs. 1–6.

C. bombayensis Børgesen, Some Indian Rhodophyceae, III, 1933, p. 127, figs. 10–12; Post, *op. cit.*, p. 61.

Frond repent, bilaterally branched, with percurrently main axis and elongated linear-lanceolate internodes up to about 260 μ broad, and as much as fourteen times as long. Branches generally better developed on one side than on the other. Blades with about six rows of cells on each side of the midrib. Tetrasporangia 45 to 60 μ in diameter, forming two elongated rows on both sides of the midrib.

Habitat. — On muddy rocks in a sheltered tidal ditch in the littoral region, Shatin, Tide Cove, in April (*Tseng 2727*) and July (*Taam A145*).

Distribution. — Ogasawara (Bonin) Islands (type locality); widely distributed from Japan in the east to East Africa in the west.

The Hong Kong specimens certainly resemble *C. bombayensis* Børg. much more than do the Japanese type. Though Post, *op. cit.*, differentiates these two species on the basis of the relative development of the lateral branches on both sides, she does not take into

consideration the great variability of plants of this genus in different environmental conditions. The writer was at first tempted to separate the two forms on the same basis. Having studied authentic species of the Japanese as well as the Bombay plants, he cannot help believing that there is a whole series of intergrading forms between *C. ogasawaraensis* on the one hand and *C. bombayensis* Børg. on the other.

C. zanzibariensis Børg. is regarded by both Okamura, *op. cit.*, and Post, *op. cit.*, as synonymous with the earlier published Japanese species. Its blade has a breadth of 250 to 400 μ and eight rows of cells on both sides of the midrib. Since the Hong Kong plant has its blade about 200 to 250 μ broad and six rows of cells on both sides of the midrib, it apparently stands between the East African and the Bombay algae. Without a certain line of demarcation between the two presumably independent species, it seems to the writer more natural to refer the various described "species" of this *Caloglossa ogasawaraensis-zanzibariensis-bombayensis* complex to a single specific entity. He sent one of these specimens to Dr. Børgesen, who made the following remark in his letter:

"Taam A145 seems to be nearest to *C. bombayensis;* the broadest thallus I have measured was 260 μ, thus somewhat thicker than the type specimens from Bombay. This plant is also *einseitig*-branched, agreeing with my figure. But I have no doubt that these plants and *Cal. ogasawaraensis* are connected by intermediate forms."

It is evident that Dr. Børgesen himself also questions the advisability of separating the two extreme forms of this complex, namely, *C. ogasawaraensis* and *C. bombayensis.*

13. Chondria hapteroclada, sp. nov.

(Plate II, Figures 1–4)

Frons fulvipurpurea, filiformis, intricata, repens, pulvinata; pulvinis valde extentis, ca. 1.5 cm. altis; filamentis teretibus, usque ad 0.72 mm. altis, pinnate decompositis, per cladohaptera rhizoidea elongata inter se adhaerentibus et ad rupes adfixis; ramis alternis vel suboppositis, apice interdum arcuatis; ramulis ultimis distichis vel tristichis, clavatis, basi leviter constrictis; apicibus ramorum ramulorumque truncatis, punctis vegetativis in foveam crateriformen immersis; in sectione transversali: cellulis epidermalibus late rect-

angularibus, 20–24 μ altis, 24–30 μ latis, cellulis pericentralibus 5, cortice crasso, circiter 5-strato; tetrasporangus usque ad 90 μ diam., in ramulis ultimis simplicibus aut ramosis ortis. Cystocarpia et acervuli spermatangiales ignota. Species Choondriae repenti Berg proxima videtur.

Specimen typicum. — *Tseng 2783* (in herbario auctoris) ad rupes arenosas zonae superioris litoralis in aqua tranquilla, prope Saiwan, Hong Kong I., 14 Mai, 1940.

Frond forming very extensive pulvinate patches to about 1.5 cm high, filiform and repeatedly, rather abundantly pinnately branched. Filaments terete, to 0.72 mm in diameter, mostly decumbent and intricately intertwined, forming haptera here and there, by which the neighboring segments adhere to one another and with which the plant attaches itself to the substratum (Pl. 11, Fig. 1). Haptera modified from ventral branchlets, unicellular rhizoids about 30 μ in diameter generally issuing at their tips (Pl. 11, Fig. 2), sometimes remaining stunted and undeveloped when two segments are too close to each other. Branches virgate, alternate or subopposite, sometimes with arcuate tips. Ultimate branchlets clavate, slightly constricted at the base, and arranged in three, sometimes two, ranks, with the ventral ones usually converted into the haptera. Apices of the branches and branchlets all truncate, with the growing point sunken in a crater-like pit. Epidermal cells in surface view hexagonal or somewhat rounded. In transverse section epidermal cells broadly rectangular, 20 to 24 μ high and 24 to 30 μ broad; pericentral cells five, surrounded by a rather thick cortex, generally four- to five-layered, with parenchymatous cells similar to them in shape and size (Pl. 11, Fig. 4). The central strand thus rather obscured, especially in the older segments. Tetrasporangia about 90 μ in diameter, scattered rather evenly in the ultimate segments, which are either simple or branched (Pl. 11, Fig. 3). Cystocarps and spermatic clusters not found.

Habitat. — Forming extensive pulvinate patches on sandy loam and muddy rocks in the upper littoral region among mangroves, Shatin, Tide Cove, in April (*Tseng 2728*), and Saiwan, Hong Kong I., in May (*Tseng 2793*, TYPE).

The present species, a member of the subgenus *Coelochondria*, is most closely related to *C. repens* Berg, from Easter Island. The latter species is, however, a very small epiphyte on other algae; it is

only about 1 to 2 mm. high, with filaments 0.2 to 0.4 mm. broad, sparsely and rather irregularly branched, and with obovate branchlets.

14. *Chondria lancifolia* Okam.

(Plate II, Figures 5–7)

Okamura, Icones of Japanese Algae, VII, v, 1934, p. 43, pl. 323, figs. 1–10.

Frond small, slender, epiphytic, bright red, to about 1 cm. high. Basal parts prostrate, attaching to the host by means of short, stout bundles of rhizoidal fibers. Erect parts once or twice alternately pinnately branched with flattened, leaflike blades about 0.17 mm. thick and up to 0.65 mm. broad, deeply constricted at the base and tapering above into fine points (Pl. II, Fig. 5). Apex convex and acute, with a large protruding apical cell. Branches sometimes firmly attaching to one another by emitting adhesive rhizoidal fibers (Pl. II, Fig. 5). Trichoblasts dichotomously branched and developed alternately near the tips (Pl. II, Fig. 6). Transverse section of the leaflike branch showing five pericentral cells surrounding a large central cell, and many large medullary cells bounded by a more or less differentiated layer of epidermal cells about 12 to 18 μ broad at the periphery (Pl. II, Fig. 7). Lenticular thickenings at the walls of the medullary cells present, especially in older portions, and in some places clearly visible through the cortex in surface view. Materials all sterile.

Habitat. — On Caulerpa, drifted ashore, Clearwater Bay, Port Shelter, in February (*Taam A33b*).

Distribution. — Warmer parts of Japan on the coasts of both the Pacific Ocean and the Japan Sea.

This species is a very characteristic one among the Platychondria and is easily recognized by its epiphytic habit, its sparingly and alternately pinnate frond, its irregularly placed bundles of rhizoidal fibers, its branches deeply constricted at the base and tapering above to sharply acute apices, and its lenticular thickenings in the medullary cells. The Hong Kong plants are sterile and much smaller in all respects than the typical Japanese ones. Nevertheless, the writer feels quite convinced that his plant represents young stages of the same species. This species is among the rare components of the Chinese marine flora.

15. *Lophosiphonia subadunca* (Kütz.) Falk.

Falkenberg, Die Rhodomelaceen, 1901, p. 496; Howe, Bahama Algae, 1920, p. 274; Børgesen, Marine Algae from the Iranian Gulf, 1939, p. 132.

Polysiphonia subadunca Kützing, Phycologia generalis, 1843, p. 418; *idem*, Tabulae phycologicae, XIII, 1863, pl. 32, figs. a–c; J. G. Agardh, Species . . . algarum, III, iii, 1863, p. 1064; Hauck, Meeresalgen, 1885, p. 235.

Hutchinsia obscura C. A. Agardh, Species algarum, II, 1828, p. 108 (fide Howe, *op. cit.*).

Polysiphonia barbatula Kützing, Phycologia generalis, 1843, p. 417; *idem*, Tabulae phycologicae, XIII, pl. 33, figs. a–d.

Polysiphonia pygmaea Kützing, Phycologia germanica, 1843, p. 313; *idem*, Tabulae phycologicae, XIII, 1863, pl. 29, figs. a–d.

Frond with long shoots and main filaments horizontally creeping, attaching by means of stout unicellular rhizoids about 30 μ in diameter, which are separated from the mother pericentral cells by a cross wall or, in some, by a small cell. Dwarf shoots erect, dorsally issued. Long shoots lateral, occurring at intervals of two to seven segments. Branches generally all simple, strongly ventrally curved when young, reaching a height of 5 mm. and having as many as fifty segments, more commonly thirty to forty. Trichoblasts very well developed on the upper parts of the dwarf shoots, each with a large basal cell of about 35 μ in diameter and three to five times subdichotomously branched. Main filaments and long shoots about 90 to 120 μ in diameter and the dwarf shoots, 60 to 90 μ in diameter, tapering to about 30 μ in diameter at the distal ends. Segments about as long as broad throughout, becoming very much shortened near the tips. Tetrasporangia about 60 μ in diameter, occurring in short spiral series of six to nine in the upper parts of the dwarf shoots.

Habitat. — Forming intricate patches on muddy loam among mangroves in the upper littoral region, Taipohui, Tolo Harbour, in April (*Tseng 2733*); on bark of mangroves near the upper littoral region, Shatin, Tide Cove, in April (*Tseng 2754*); on mud-covered rocks among mangroves in the littoral region, Shatin, Tide Cove, in July (*Taam A144*); intermingled with Caloglossa and Bostrychia, on mud-covered barks of mangrove trees near the upper littoral region, Aberdeen, Hong Kong I., in July (*Tseng 2575b*).

Distribution. — Corsica, Mediterranean Sea (type locality) and southern Europe; Bahama Is.; Iranian Gulf.

The identification of the Hong Kong plant with the Corsican alga is made with some reservation. The type specimen, according

to Falkenberg, *op. cit.*, has six pericentral cells. In the works cited J. G. Agardh, Hauck, and Børgesen all give similar reports. Howe, *op. cit.*, however, credits this species with a variable number of pericentral cells varying from six to ten. In the Hong Kong specimens the writer has found the number of these cells to vary from six to eight. Since his plant agrees in all other respects with the others mentioned above, he has to share the view of Howe, and, for the time being at least, to be content with the determination given. It is to be noted that Howe's plant was found on surf-beaten rocks, whereas the writer's were from a very sheltered mangrove swamp. The Bahama plants are more yellowish and smaller than those from Hong Kong. Otherwise they agree perfectly well with each other. The Chinese plants are also somewhat larger than the Iranian alga, which Børgesen reports to be only 90 μ in diameter.

SUMMARY

Fifteen species of marine algae are added to the floristic list of Hong Kong. All these are recorded for the first time from Chinese waters. One species is here described as new, namely, *Chondria hapteroclada*, which belongs to the subgenus Coelochondria, and is closely related to *C. repens* Børg. from Easter Island.

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EXPLANATION OF PLATE I

FIG. 1. *Achrochaetium arcuatum* (Drew), comb. nov. Two young plants, showing basal cells and branching. × 553

FIG. 2. *A. robustum* Børg. Basal part of a plant, showing a basal cell. × 188

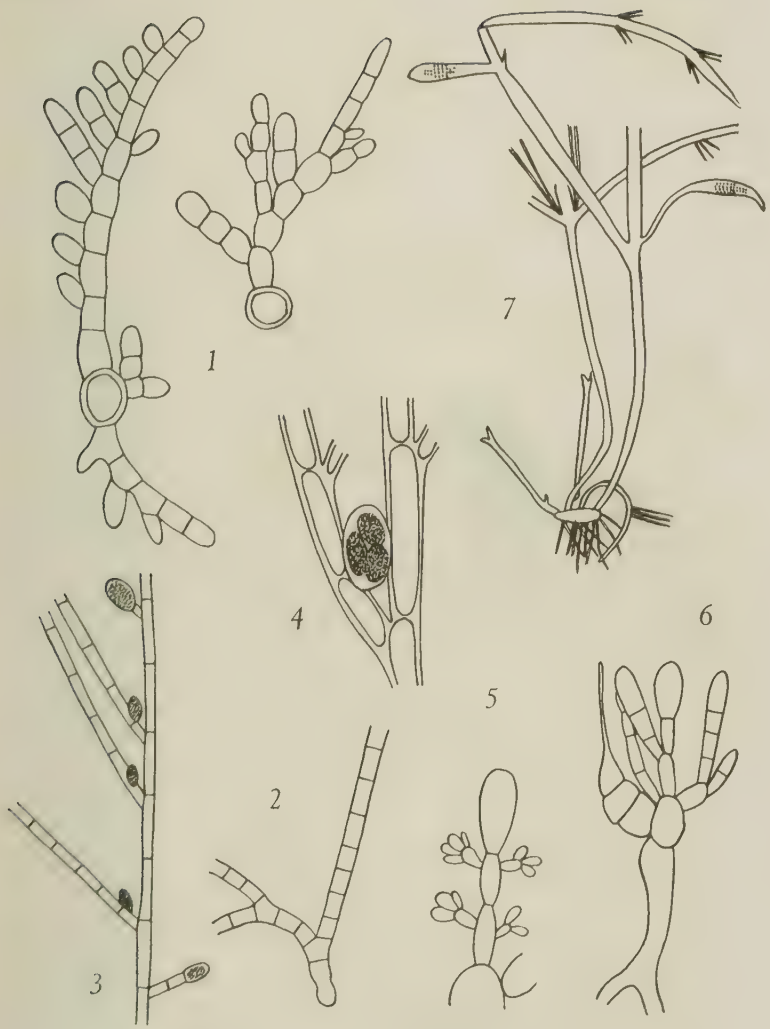
FIG. 3. *A. robustum* Børg. Part of a plant, showing five monosporangia. × 188

FIG. 4. *A. robustum* Børg. Part of a branch bearing a tetrasporangium. × 553

FIG. 5. *Dermonema gracilis* (v. Mart.) Schmitz. Part of a cortical filament bearing spermatangia. × 553

FIG. 6. *D. gracilis* (v. Mart.) Schmitz. Cortical filament bearing a carpogonial branch. × 307

FIG. 7. *Caloglossa ogasawaraensis* Okam. Habit sketch of a tetrasporiferous plant. × 9



Marine algae from Hong Kong

EXPLANATION OF PLATE II

FIG. 1. *Chondria hapteroclada*, sp. nov. Habit sketch showing the branching and the rhizoids. × 4

FIG. 2. *C. hapteroclada*, sp. nov. Lateral view of a filament showing two branchlets and a third one modified to become a hapteron with terminal rhizoids. × 17

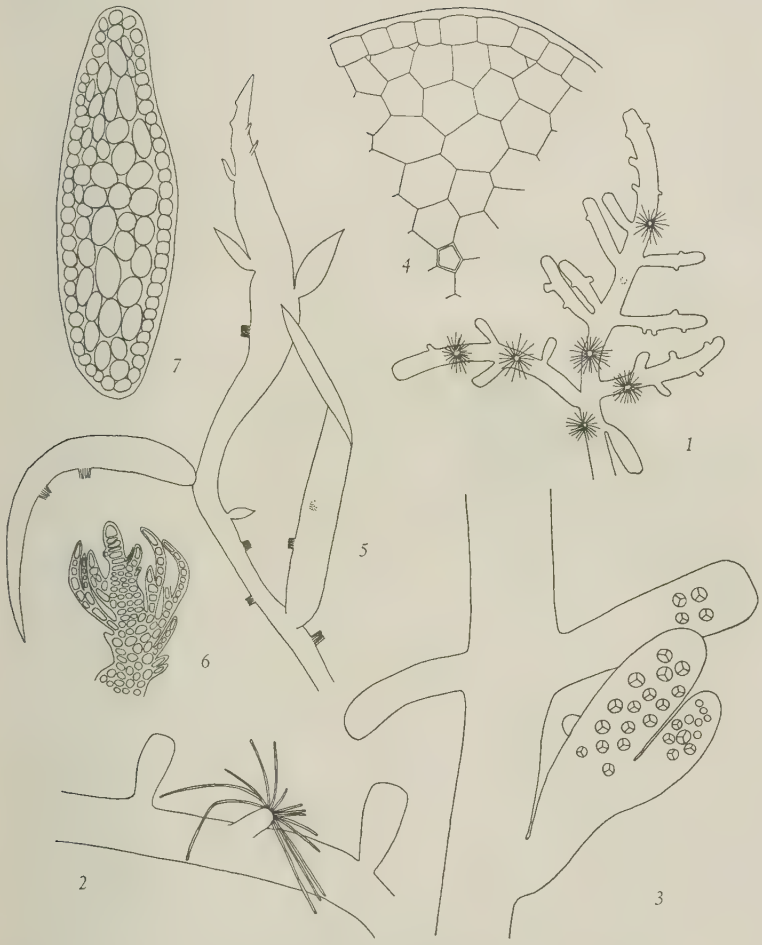
FIG. 3. *C. hapteroclada*, sp. nov. Part of a branch with tetrasporangia. × 17

FIG. 4. *C. hapteroclada*, sp. nov. Tranverse section of a branchlet. × 158

FIG. 5. *C. lancifolia* Okam. Habit sketch showing the branching and the rhizoids. × 12

FIG. 6. *C. lancifolia* Okam. Apex of a branch. × 203

FIG. 7. *C. lancifolia* Okam. Transverse section of a branch. × 100



Marine algae from Hong Kong

FORESTRY

SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. XVI *

DOW V. BAXTER

THERE are many classical papers and other reports that deal with the decay of wood in culture by various fungi. No systematic attempt, however, has heretofore been made to compare the reactions of a large group of isolates on similar substratum of many different species of resupinate polypores collected from widely separated localities of the continent and found on a great variety of woods. I have based this paper on a large number of species and races obtained in culture from the Michigan collections. Each isolate was placed on red-gum and white-pine blocks regardless of the kind of wood originally attacked by the organism. The macroscopic effects of these fungi upon these test woods have been noted and, furthermore, records of the mycelial growth on malt extract in petri-dish cultures have been secured.

Distinctions that can be made between many species and races of the white resupinate polypores in such cultures have been recorded in key form in Paper XV (29 [1943]: 85–109) of this series. The limitations of methods that may be used to distinguish the resupinate polypores are likewise discussed in that account. The key there presented is continued in the present paper, which deals with the light- and dark-colored species of the group.

As in the previous paper, all growth measurements are averages

* Throughout the work on these monographs I have been indebted to many individuals and institutions for suggestions, help, and privileges. My appreciation is expressed particularly to the men who accompanied me on my ten expeditions to Alaska, the Yukon Territory, and the Northwest Territories. They aided in the collection and care of specimens, sometimes under rather difficult circumstances. I am under obligation to Professors T. G. Halle and Gunnar Samuelson, of Naturhistoriska Riksmuséet in Stockholm, with whom I have had the pleasure of being associated. Thanks are due to several American institutions and scholars, also: to the authorities at the New York Botanical Garden; to Dr. W. H. Long, Albuquerque, New Mexico; to the staff of the Division of Pathological and Mycological Collections of the United States Department of Agriculture; and to Professor H. H. Bartlett and Mr. Reed W. Varner, of the University of Michigan.

of the two longest radii emanating from the inoculum, which was not measured.

The color terms enclosed in quotation marks are those of R. Ridgway, *Color Standards and Color Nomenclature* (1912).

KEY TO THE PRINCIPAL LIGHT-COLORED RESUPINATE POLYPORES IN CULTURE

The light-colored mycelium in both petri-dish tests and one-year-old wood-block cultures characterizes the resupinate polypores listed in this key. In general, the key does not include those plants which have "avellaneous" or brown mycelium. Certain species with fruiting bodies that are brown or of a dark color are grouped here, however, since they either exhibit a light-colored mycelium for a number of weeks or show light-colored as well as dark-colored mycelium in cultures. *Lenzites trabea*, for example, is often salmon, i.e. "capucine buff," in young cultures. Likewise, certain white resupinate polypores, such as *Poria unita*, are included in this key since mycelial colors change from white to yellow, depending upon environmental conditions, especially the degree of darkness. *Poria cocos* is actually a white plant, but the mycelium may be "cinnamon" or "Mikado brown" as well as white. It is placed in the light-colored group. No attempt has been made to revise generic concepts in this key. Generic names that are usually applied to the species are employed throughout.

KEY TO LIGHT-COLORED RESUPINATES

1. Cultures forming thick sheets of mycelium that develop so luxuriantly that the fungus extends between the lid and the dish or grows up over the lid of the petri dish for several millimeters at 30° C..... 2
1. Cultures not forming such thick sheets or showing such mycelial growth within two weeks that the fungus grows out between the lid and the dish or up over the lid of the petri dish at 30° C..... 5

2. Mycelium distinctly pink, i.e. "pale vinaceous fawn," at 25° C.
Poria rufa[1] on *Picea glauca*, Fort Wrigley, Northwest Territories (mycelium fills petri dish at 35° C.). Pl. I, Fig. 1

[1] These three isolates cannot be distinguished in one-year-old red-gum block cultures. This might well indicate that the ponderosa-pine fungus and the isolate from *Taxodium distichum* belong to *Poria rufa*. Colors for each of the three fungi in one-year-old flasks are whitish to "Sayal brown," and the brown is conspicuous. Both petri-dish and flask cultures seem to indicate that these isolates may be of the same species.

Unknown Poria on *Pinus ponderosa*, locality not specified (mycelium fills petri dish at 35° C.)

Unknown Poria on *Taxodium distichum*, railroad ties, Georgia. (Mycelium occasionally fills petri dish at 35° C., but average of tests is 20 mm. Variation in rate of growth not significant, and mycelium in petri dishes and in flasks appears to be almost identical with the other fungi in this section of the key.)

2. Mycelium not pink but white, yellowish cream, or salmon at 25° C..... 3

3. Mycelium white, "avellaneous," "vinaceous buff," or yellowish at 25° C.. 4

3. Mycelium cream or salmon, i.e. "capucine buff," at 25° C.

Lenzites trabea ex U. S. Division of Forest Pathology, Forest Products Laboratory, Madison. Pl. I, Fig. 2

4. Mycelium white or yellowish and filling petri dish at 25° C. in two-week-old cultures

Poria unita on *Quercus sp.*, Michigan (pore formation evident). Pl. I, Fig. 3

Poria unita pulchella, Selkirk, Yukon Territory (pore formation evident). Pl. I, Fig. 4

Poria unita pulchella U. 26 on *Populus balsamifera*, Burnt Island, Great Slave Lake, Northwest Territories (pore formation evident). Pl. II, Fig. 1

4. Mycelium white or "avellaneous" or "vinaceous buff" at 25° C. and usually not filling dish (i.e. showing growth of approximately 30 or 35 mm. at 25° C.)

Poria nigra ex U. S. Division of Forest Pathology, Washington, 71073. Pl. IV, Fig. 3

5. Culture exhibiting more than 15 mm. growth at 30° C. and usually filling the petri dish at this temperature 6

5. Culture exhibiting not more than 15 mm. growth at 30° C.

Polyporus alboluteus on *Picea sitchensis*, Juneau, Alaska. Pl. II, Fig. 2

6. Culture filling petri dish in two-week-old test at 35° C., but not including those that are arachnoid or water-soaked in appearance, mycelium white or yellow, not pink or some other color

Poria unita on *Quercus sp.*, Michigan (pore formation evident). Pl. I, Fig. 3

Poria unita pulchella, Selkirk, Yukon Territory (pore formation evident). Pl. I, Fig. 4

Poria unita pulchella U. 26 on *Populus balsamifera*, Burnt Island, Great Slave Lake, Northwest Territories (pore formation evident). Pl. II, Fig. 1

6. Culture not filling petri dish in two-week-old test at 35° C., or, if filling dish, arachnoid or water-soaked in appearance, mycelium white, yellow, pink, or some other color 7

7. Mycelium exhibiting a growth of more than 15 mm. at 35° C..... 8
7. Mycelium exhibiting a growth of less than 15 mm. at 35° C..... 9

8. Mycelium on agar surface distinctly pink or orange at 35° C.; not appressed

Poria spissa on hardwood, Michigan (pore formation evident). Pl. II, Fig. 3

Poria semitincta on *Quercus marilandica*, North Carolina (fungus variable in culture, i.e. sometimes not distinctly pink and at times appressed, but occasionally falling in this section of key because of growth rates and temperature relations. Readily distinguished from *Poria spissa* by lack of orange color; see 13). Pl. II, Fig. 4

Fomes subroseus on *Larix laricina*, Michigan. (Fungus variable in culture at this temperature, and sometimes it is not distinctly pink within the time limit of the test. It can readily be separated from cultures of *Poria spissa* and *Poria semitincta* by the nodular type of pore formation produced on wood blocks.) Pl. IV, Fig. 1

8. Mycelium on agar surface not pink;[2] appressed, especially about inoculum, or arachnoid at 35° C..... 14

9. Culture appearing water-soaked at 25° C., i.e. growth thin so that mycelium does not mask agar from view; somewhat arachnoid 13
9. Culture not appearing water-soaked but forming a somewhat thicker growth at 25° C., so that the mycelium appears more cottony than arachnoid 10

10. Mycelium throughout culture white to "cinnamon buff" at 25° C. and not exhibiting a uniform type of growth, i.e. mycelium forming a definitely cottony ring of "cinnamon buff" mycelium about the inoculum

Poria mutans tenuis on *Castanea dentata*, Georgia. Pl. III, Fig. 1

10. Mycelium exhibiting a more or less uniform color throughout culture and also a uniform type of growth at 25° C..... 11

11. Mycelium in the form of thick strands that radiate from the inoculum at 25° C.

Poria incrassata ex U. S. Division of Forest Pathology, Forest Products Laboratory, Madison. Pl. III, Fig. 2

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[2] *F. subroseus* is pinkish in older cultures and especially on wood blocks. The color is not always evident in two-week-old cultures at this temperature.

11. Mycelium not in the form of thick strands that radiate from the inoculum at 25° C..... 12

12. Mycelium white to "avellaneous," not pink at 25° C..... 15

12. Mycelium showing pink at 25° C..... 16

13. Culture exhibiting growth on agar surface at 35° C.

A. Mycelium in one-year-old red-gum block cultures flocculent, somewhat nodulose, growth so luxuriant that the edges and shape of the blocks are generally hidden

Poria spissa on hardwood, Michigan (fungus readily distinguished from *Poria semitincta*, particularly in petri-dish or younger flask cultures, by the bright pink and orange mycelium of *Poria spissa*). Pl. II, Fig. 3

A. Mycelium in one-year-old red-gum block cultures more arachnoid than flocculent, not nodulose, edges and shape of wood blocks distinct

Poria semitincta U. 23 on *Quercus marilandica*, North Carolina (colors of mycelium not bright as in *Poria spissa* and definitely not orange). Pl. II, Fig. 4

13. Culture not exhibiting growth on the agar surface at 35° C.

Poria eupora on *Quercus borealis maxima*, Michigan. Pl. III, Fig. 3

14. Mycelium yellowish, especially about the inoculum, at 35° C.

Poria luteofibrata on *Pinus rigida serotina*, Florida. Pl. III, Fig. 4

14. Mycelium not yellowish

A. One-year-old red-gum block cultures pinkish; nodular type of fruiting structures present

Fomes subroseus on *Larix laricina*, Michigan. Pl. IV, Fig. 1

A. One-year-old red-gum block cultures brown as well as white; nodular type of fruiting structures not present

Poria cocos ex U. S. Division of Forest Pathology, Washington, 72199, from sclerotium, Florida (no pore formation within two weeks, but pores form in older test cultures. Mycelium whitish to "avellaneous," cottony and not chamois-like as in isolates of *Poria unita*)

Poria cocos ex U. S. Division of Forest Pathology, Washington, on ash, Vermont, det. Davidson (no pore formation within two weeks; mycelium whitish to "avellaneous," cottony and not chamois-like as in isolates of *Poria unita*)

15. Mycelium granular, i.e. mealy in appearance, at 25° C.

Poria purpurea on *Pinus contorta*, Jasper National Park, Alberta. Pl. IV, Fig. 2

15. Mycelium not granular in appearance at 25° C.
    A. Mycelium in one-year-old red-gum block cultures nodular, fruit formation often appearing as pink nodular structures; culture more pinkish than brown
        Fomes subroseus on *Larix laricina*, Michigan. Pl. IV, Fig. 1
    A. Mycelium in one-year-old red-gum block cultures not distinctly nodular, fruit formation (if present) not in the form of pink nodular structures; culture more chocolate brown than pink
        Poria nigra ex U. S. Division of Forest Pathology, Washington, 71073. Pl. IV, Fig. 3
        Poria nigra ex U. S. Division of Forest Pathology, Washington, 71099, on *Quercus velutina*, Illinois. Pl. IV, Fig. 4
        An isolate of *Poria nigra*, 71118, is not included in this group since this fungus lacks the color which distinguishes the group.

16. Mycelium granular, i.e. mealy, at 25° C. in two-week-old tests
    Poria purpurea on *Pinus contorta*, Jasper National Park, Alberta. Pl. IV, Fig. 2
16. Mycelium not granular at 25° C. in two-week-old tests
    A. One-year-old red-gum block cultures exhibiting fructifications, often in the form of pink nodules; mycelium not masking the block edges or shape of the test pieces from view
        Fomes subroseus on *Larix laricina*, Michigan. Pl. IV, Fig. 1
    A. One-year-old red-gum block cultures not exhibiting conspicuous nodules that usually produce pores; mycelium growing luxuriantly over the blocks, so that the shape of the test pieces is masked from view
        Poria spissa on hardwood, Michigan (fungus readily distinguished from *Fomes subrosea*, particularly in petri-dish or younger flask cultures, by the bright pink and orange mycelium of *Poria spissa*). Pl. II, Fig. 3

KEY TO THE PRINCIPAL BROWN RESUPINATE POLYPORES IN CULTURE

The brown-colored mycelium in both petri-dish tests and one-year-old wood-block cultures characterizes the resupinate polypores listed in this key. The group includes both the woody Fomes-like forms and the annuals. No attempt has been made to revise generic concepts, and the names presented are those usually applied to the plants. Several of the species have light-colored or even white

mycelium at first. White plants such as isolates of *Poria cocos* often have brown mycelium in culture. These are not included in the key, since they have been placed in the light-colored or white groups.

KEY TO BROWN RESUPINATES

1. Mycelium filling petri dishes in two-week-old tests or cultures exhibiting a growth of at least 25 mm., and usually more luxuriant at 35° C..... 2
1. Mycelium showing a growth of 25 mm. or less in two-week-old tests at 35° C..... 7

2. Culture exhibiting a luxuriant growth at 35° C., i.e. mycelium growing up and over the sides and cover of the petri dish in two-week-old tests; dark yellow brown, i.e. "yellow ocher," often with dark red brown, i.e. "Rood brown," areas much in evidence at 25° C. in two-week-old cultures; but the red brown later turning to dark brown, i.e. "Saccardo's umber," and not showing red at all. Red not characteristic or not found at all in wood-block cultures or in old petri-dish tests (the most rapidly growing resupinate at 35° C. of all isolates of the brown group)
Fomitiporia dryophila, Race II, on Carpinus, Louisiana. Pl. V, Fig. 2
2. Mycelium exhibiting excellent growth at 35° C., but not developing fast enough within a two-week period to cover the interior sides of the dish and lid; mycelium not dark yellow brown, i.e. often more whitish or "avellaneous" mycelium present, "chamois" to "clay color" and never exhibiting red brown 3

3. Culture exhibiting black or dark line formation on the mycelium in two-week-old tests and showing a broad (approximately 1 cm. wide) white border, especially at 25° C. This is in marked contrast to the brown mycelium that surrounds the inoculum.
Poria inermis on *Ilex verticillata*, Michigan. (Compare *Poria Andersonii*, which is similar in having black line and agar discoloration, but does not have the distinct white border). See Pl. XXX, Fig. 1 of Paper VIII of this series (22 [1936]: 275–296)
3. Culture not exhibiting definite black line formation on the mycelium in two-week-old tests or, if black lines are present, not showing a wide conspicuous border of white mycelium that surrounds the brown hyphae of the remaining parts of the culture 4

4. Mycelium exhibiting bristle-like spines on the hyphae as seen under the microscope; setal hyphae often present
Poria spiculosa ex U. S. Division of Forest Pathology, Washington, on *Carya sp.* (Red-gum block cultures with lines present but not conspicuously so. Basidiospores not produced.) Pl. V, Fig. 3
Poria Andersonii ex U. S. Division of Forest

Pathology, Washington, substratum and locality not specified. (Red-gum block cultures marked with conspicuous lines. Basidiospores sometimes produced.)

4. Mycelium not exhibiting bristle-like spines on the hyphae as seen under the microscope; setal hyphae not present 5

5. Culture exhibiting a uniform type of growth 6

5. Culture not exhibiting a uniform type of growth but radiating instead, or patchy

A. Mycelium in one-year-old wood-block cultures yellow brown and completely enveloping the test blocks; covered with a thick mycelial mat

Fomitiporia flavomarginata on *Quercus nigra*, South Carolina. Pl. VI, Fig. 3

A. Mycelium in one-year-old wood-block cultures not yellow brown but whitish to chocolate brown; test blocks thinly covered with mycelium ..... B

B. Cultures fruiting

Lenzites trabea ex U. S. Division of Forest Pathology, Forest Products Laboratory, Madison. Pl. I, Fig. 2

B. Cultures not fruiting

Lenzites saepiaria on *Picea mariana*, Michigan. Pl. VI, Fig. 4

6. Mycelium more "cinnamon buff" to "clay color" than white at 25° C. in two-week-old tests

Fomitiporella floridana, Race II, on *Quercus phellos*, Arkansas (slight wintergreen odor, but not strong as in *Poria laevigata*). Pl. VII, Fig. 2

Fomitiporia Earleae, Race I, on *Nyssa biflora*, Florida (very slight wintergreen odor, but not strong enough to be used as a feature of distinction). Pl. VIII, Fig. 1

Fomitiporia Earleae, Race II, on *Liquidambar Styraciflua*. (No odor. It is clear that odor cannot be used to distinguish the isolates of the group.) Pl. VIII, Fig. 2

6. Mycelium more white than brown at 25° C. in two-week-old tests (growth usually less than 25 mm. in two-week-old cultures)

A. Mycelium in one-year-old wood-block tests forming thick mat over blocks; dark-red areas conspicuous over culture; no fruit formation

Fomitiporella floridana, Race I, on *Quercus nigra*, South Carolina. Pl. VII, Fig. 3

A. Mycelium in one-year-old wood-block tests not forming thick mat over blocks; red areas not present in culture; fruit formation conspicuous

Lenzites trabea ex U. S. Division of Forest Pathology, Forest Products Laboratory, Madison. Pl. I, Fig. 2

7. Mycelium exhibiting a growth of as much as 15 or 20 mm. at 35° C.; mycelium uniform in color on inoculum and on surface of agar at 35° C.

A. Mycelium in one-year-old wood-block tests exhibiting conspicuous dark-red areas, sometimes 1 cm. wide, and lines throughout culture

Fomitiporella floridana, Race I, on *Quercus nigra*, South Carolina. Pl. VII, Fig. 3

Fomitiporia Earleae, Race I, on *Nyssa biflora*, Florida. Pl. VIII, Fig. 1

A. Mycelium in one-year-old wood-block tests without conspicuous broad dark areas. (If lines are present, such lines are fine and narrow, so that red is not a conspicuous color throughout the culture.)

Fomitiporia Earleae, Race I, on *Nyssa biflora*, Florida. Pl. VIII, Fig. 1

Fomitiporia Earleae, Race II, on *Liquidambar Styraciflua*, Georgia. Pl. VIII, Fig. 2

Polyporus texanus on *Prosopis julifolia*, Texas. (Fungus differs from the isolates of *Fomitiporia Earleae* by exhibiting arachnoid or "hairy" type of growth on wood blocks, i.e. not so chamois-like or feltlike. Red lines or red areas are never present.)

7. Mycelium not exhibiting more than 10 mm. growth at 35° C. and mostly no growth at this temperature. (If as much as 10 mm. growth is exhibited at 35° C., the new mycelium on the inoculum is of a different color from that on the agar, i.e. brown on the inoculum and white on the agar.) 8

8. Mycelium filling petri dish at 30° C. or exhibiting a growth of as much as 25 mm. at this temperature 9

8. Mycelium not filling petri dish at 30° C. or culture exhibiting less than 20 mm. growth at 30° C. 12

9. Mycelium at 30° C. showing at least as much growth as 35 mm., mycelium producing a thick flocculent type of growth, cultures showing a development of 30 mm. or more at 25° C. 25

9. Mycelium not filling petri dishes at 30° C., at least with not as much growth as 35 mm. at this temperature, or, if showing approximately 35 mm., culture exhibits an agar discoloration that appears through the mycelium. Growth mostly much less than 30 mm. at 25° C. 10

10. Agar discoloration of dark purplish brown, or dark brown evident at 30° C. and showing through the mycelium at this temperature 11

10. Agar not discolored dark purplish brown or dark brown at 30° C., so that red-brown or dark areas show through the mycelium 24

11. Mycelium showing seta-like hyphae as seen under the microscope (not many small spines on the hyphae but the hyphae themselves seta-like).

Unknown resupinate X on *Betula kenaica*, Moose Pass, Alaska. Pl. VIII, Fig. 3. (Macroscopically this isolate suggests *Fomes nigricans*, but differs microscopically from that fungus.)

11. Mycelium not showing seta-like hyphae as seen under the microscope
    Fomes nigricans U. 42 on *Betula kenaica*, Moose Pass, Alaska
    Fomes nigricans on *Betula alba papyrifera*, Minnesota. Pl. VIII, Fig. 4

12. Mycelium exhibiting growth at neither 30° C. nor 25° C. within the two-week test period

    A. Mycelium in one-year-old wood-block cultures exhibiting black wavy zone lines on wood blocks
    Fomes nigrolimitatus 8 F. on *Tsuga heterophylla*, Wrangell, Alaska. Pl. IX, Fig. 1
    Fomes nigrolimitatus 7 F. on *Tsuga heterophylla*, Tyee, Alaska

    A. Mycelium in one-year-old wood-block cultures not exhibiting black line formation on wood
    Poria ferrea 9 on *Abies sp.*, Oregon. Pl. XII, Fig. 4
    Poria ferrea on *Alnus sinuata*, Skagway, Alaska. Pl. XI, Fig. 3
    Poria ferruginosa on *Prunus serotina*, Michigan. Pl. XIII, Fig. 3

12. Mycelium exhibiting growth at 30 or 25° C., or at least new growth occurring on inoculum 13

13. Mycelium exhibiting agar discoloration at 30° C. that shows from beneath the mycelium 14
13. Mycelium not exhibiting agar discoloration at 30° C. that can be seen beneath the mycelium 15

14. Agar yellow green as seen from beneath the culture (the yellow green "mignonette green" characteristic of agar in older cultures)
    Polyporus radiatus on *Betula kenaica*, Moose Pass, Alaska. Pl. IX, Fig. 2
14. Agar discolored red brown beneath culture
    Unknown resupinate X on *Betula kenaica*, Moose Pass, Alaska. Pl. VIII, Fig. 3. (Macroscopically this isolate suggests *Fomes nigricans*, but differs microscopically from that fungus.)
    Polyporus glomeratus ex Central Experimental Farm, Canada, 11254, on *Acer sp.*, Burnet, Quebec. (Mycelium somewhat arachnoid in wood-block cultures and not forming a dense chamois-like mat over the surface of the test piece as in the isolate classed as unknown on Betula.)

15. Mycelium exhibiting growth of as much as 15 mm. and usually more at 25° C. 18
15. Mycelium not exhibiting as much growth as 15 mm. on agar surface at 25° C. 16

16. Mycelial growth hiding outline of inoculum at 30° C., with fluffy growth, but not forming definite growth on surface of agar
Fomes Everhartii on *Quercus borealis maxima*, Michigan. Pl. IX, Fig. 3

16. Mycelial growth not hiding outline of inoculum at 30° C., with fluffy growth, but showing some growth on agar surface 17

17. Mycelium on agar surface cottony at 30° C.
Poria Tsugina on *Abies concolor*, Colorado. Pl. X, Fig. 2

17. Mycelium silky to chamois-like at 30° C. or no growth at all on agar surface

A. Mycelium in one-year-old wood-block cultures chamois-like; brown; culture definitely not whitish — wavy brown lines often present
Poria Tsugina on *Tsuga heterophylla*, British Columbia. Pl. X, Fig. 3
Poria Tsugina on *Tsuga canadensis*, Michigan. Pl. X, Fig. 4

A. Mycelium in one-year-old wood-block cultures brown and white, but not totally brown and usually more white than brown; mycelium usually more flocculent than chamois-like, wavy brown lines not present
Trametes isabellina 6 W. on *Picea glauca*, Selkirk, Yukon Territory. Pl. XI, Fig. 1
Trametes isabellina 10 W. on *Picea glauca*, Selkirk, Yukon Territory. Pl. XI, Fig. 2
Poria ferrea 9 on *Abies sp.*, Oregon
Poria ferrea on *Alnus sinuata* Skagway, Alaska. Pl. XI, Fig. 3
Poria ferrea on *Alnus rubra*, Oregon. Pl. XI, Fig. 4
Poria ferrea on *Acer macrophyllum*, Oregon. Pl. XII, Fig. 1
Poria ferrea on *Corylus sp.*, Oregon. Pl. XII, Fig. 2
Poria ferrea ex Central Experimental Farm, Canada, 11253, substratum unknown, Burnet, Quebec
Poria ferruginosa 33 on *Thuja plicata*, Oregon
Poria ferruginosa on *Prunus serotina*, Michigan. Pl. XIII, Fig. 3

18. Culture exhibiting a mat of mycelium of at least a few millimeters (3 or more) on the surface of the agar at 30° C. 19

18. Culture not exhibiting a mat of mycelium on the agar at 30° C. 22

19. Mycelium exhibiting a cerebriform type of growth at 25° C., or mycelium extending out in fanlike growth from the inoculum
Trametes isabellina 6 W. on *Picea glauca*, Selkirk, Yukon Territory. Pl. XI, Fig. 1
Poria ferrugineofusca on *Pseudotsuga taxifolia*, Oregon. Pl. XIV, Fig. 3

19. Mycelium not exhibiting a cerebriform type of growth at 25° C.; mycelium growing uniformly about inoculum, i.e. not radiating in fanlike type of growth 20

20. Mycelium definitely exhibiting brown colors at 25° C. and as much brown as white or more brown than white, also at 30° C. showing more brown than white 21

20. Mycelium on agar more white than brown at 30 and 25° C.

Poria ferrugineofusca ex Canadian Forest Products Laboratory, F8221A

Poria ferrugineofusca on *Pseudotsuga taxifolia*, Oregon. Pl. XIV, Fig. 1

21. Mycelium red brown, i.e. "Sayal brown" or "avellaneous"

A. Mycelium in one-year-old wood-block tests uniform in color

Poria Weirii on *Thuja plicata*, locality not specified. Pl. XIV, Fig. 2

A. Mycelium in one-year-old wood-block tests whitish and brown, i.e. not of the same color throughout the culture

Poria ferrugineofusca on *Tsuga heterophylla*, Skagway, Alaska

21. Mycelium not red brown but "chamois" or "cream buff"

A. Mycelium in one-year-old red-gum wood-block cultures forming a thin white rhizomorphic growth over test pieces

Poria ferruginosa on *Thuja occidentalis*, Minnesota. Pl. XIII, Fig. 2

Poria ferrea ex Central Experimental Farm, Canada, 11253, substratum unknown, Burnet, Quebec

A. Mycelium in one-year-old red-gum wood-block cultures not forming a thin white rhizomorphic growth over wood test pieces; mycelium completely enveloping the blocks and masking them from view .. B

B. Black or brown lines conspicuous in wood-block cultures

Poria punctata on *Rhus vernix*, Michigan

B. Black or brown lines not present, or at least not conspicuous in wood-block cultures

Poria prunicola on *Prunus serotina*, Michigan. Pl. XIV, Fig. 3

22. Mycelium exhibiting a concentric ring growth at 25° C.

Trametes isabellina 10 W. on *Picea glauca*, Selkirk, Yukon Territory. Pl. XI, Fig. 2

22. Mycelium not exhibiting concentric ring growth at 25° C..... 23

23. Culture uniformly brown in two-week-old tests

A. Mycelium of uniform color in one-year-old red-gum block cultures

Poria Weirii on *Thuja plicata*, locality not specified. Pl. XIV, Fig. 2

A. Mycelium not uniform in color in one-year-old red-gum block cultures but varying in different shades of brown and appearing, because of color, patchy

Poria ferrugineofusca on *Pseudotsuga taxifolia*, Oregon. Pl. XIV, Fig. 1

23. Culture predominantly white with areas of brown mycelium in two-week-old tests

Poria ferrea on *Salix sp.*, Oregon (grows faster than all other isolates, i.e. 30 mm. at 25° C.). Pl. XII, Fig. 3

Poria ferrea on *Alnus rubra*, Oregon (20 mm. growth at 25° C.). Pl. XI, Fig. 4

Poria ferrea on *Acer macrophyllum*, Oregon (15 mm. growth at 25° C.). Pl. XII, Fig. 1

Poria ferrea on *Corylus sp.*, Oregon (15 mm. growth at 25° C.). Pl. XII, Fig. 2

Poria ferruginosa [3] on *Acer saccharum*, Michigan (23 mm. growth at 25° C.). Pl. XIII, Fig. 1

Poria ferruginosa on *Prunus serotina*, Michigan. Pl. XIII, Fig. 3

Poria ferruginosa 33 on *Thuja plicata*, Oregon (15 mm. growth at 25° C.) Pl. XIII, Fig. 4

24. Isolates from coniferous woods

A. Mycelium on one-year-old red-gum block cultures forming a thin white rhizomorphic growth over the wood

Poria ferruginosa on *Thuja occidentalis*, Minnesota. Pl. XIII, Fig. 2

A. Mycelium in one-year-old red-gum block cultures not forming a thin white rhizomorphic growth over the wood

Poria ferrugineofusca on *Pseudotsuga taxifolia*, Oregon (not so whitish as western hemlock isolate; red-brown mycelium conspicuous). Pl. XIV, Fig. 1

Poria ferrugineofusca on *Tsuga heterophylla*, Skagway. (This isolate forms a cream-colored or whitish smooth mycelial mat over blocks with red-brown mycelium present in culture. Culture much more whitish than Douglas fir isolate)

24. Isolates from hardwoods

Fomes robustus on *Betula nigra*, Virginia (predominating colors of cultures mostly "warm buff" or "antimony yellow" as in *F. Everhartii;* no "plug" found as in *F. Everhartii*). Pl. XIV, Fig. 4

Fomitiporia dryophila, Race I, on *Quercus sp.*, Florida (predominating colors of cultures yellower than those of *F. robustus* or *F. Everhartii*, i.e. "cream color" or

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[3] *Poria ferruginosa* on *Thuja occidentalis* exhibits a growth of 25 mm. at 25° C. Since this isolate grows approximately 20 mm. at 30° C., it is not grouped here. The isolate on maple did not grow at 30° C.

"Naples yellow"; plugs of mycelium not formed as in *F. Everhartii*). Pl. V, Fig. 1

Fomes Everhartii (form *dryophila*, undescribed) on *Quercus sp.*, Oklahoma (mycelium growing so luxuriantly within flask that a distinct "plug" is formed which eventually envelops both agar and wood blocks so as to pull the media away from the bottom of the container). Pl. IX, Fig. 4

Fomes Everhartii on *Quercus imbricaria*, Michigan (mycelium growing so luxuriantly within flask that a distinct "plug" is formed which eventually envelops both agar and wood blocks so as to pull the media away from the bottom of the container). Pl. X, Fig. 1

25. Mycelium with wintergreen odor in two-week-old petri-dish cultures at 30° C.

A. Mycelium in one-year-old red-gum block cultures exhibiting nodular growth

Poria laevigata on *Acer sp.*, Michigan (mycelium not forming growth over white-pine blocks in one-year-old tests). Pl. V, Fig. 4

Fomes nigricans on *Betula alba papyrifera*, Minnesota (mycelium covering white-pine blocks in one-year-old tests, i.e. *Fomes nigricans* grows more readily on white pine than does the superficial mycelial growth of *Poria laevigata* over test pieces). Pl. VIII, Fig. 4

A. Mycelium in one-year-old red-gum block cultures not exhibiting nodular growth

Fomitiporella floridana?,[4] Race I, on Carpinus, Great Falls, Virginia. (One-year-old cultures of all races of *Fomitiporella floridana* are more whitish than those of all races of *Fomitiporia Earleae*. The predominating colors of all races of *F. Earleae* are generally similar to those of *Fomes Everhartii*, i.e. mostly "warm buff" or "antimony yellow.") Pl. VII, Fig. 1

Fomitiporia Earleae,[4] Race II, on *Liquid-*

[4] The presence of red lines or red crustlike areas is common to the races of *Fomitiporella floridana* and of *Fomitiporia Earleae*. Wood-block cultures of these fungi that are one year old have demonstrated that the predominantly "hematite-red" areas that appear in cultures are not restricted to those of *Fomitiporia Earleae*, but occur in *Fomitiporella floridana* as well. These red areas or lines appear in wood-block cultures, but may not be evident in younger agar cultures.

ambar Styraciflua, Georgia. (This fungus exhibits a few black lines in one-year-old red-gum block cultures, mycelium not plugging up flasks. Slight or no wintergreen odor, so that isolate is included in both sections of key. One-year-old cultures of all races of *Fomitiporia Earleae* are more yellowish than those of all races of *Fomitiporella floridana*. The predominating colors of *Fomitiporia Earleae* are not whitish, but similar to those of *Fomes Everhartii*, i.e. "warm buff" or "antimony yellow.") Pl. VIII, Fig. 2

Poria laevigata on *Betula occidentalis*, British Columbia. *P. betulina* is a synonym. (White pine blocks are either not at all or scarcely attacked by this fungus in one-year-old tests. This feature is generally characteristic for cultures of most isolates of *P. laevigata*, and it can be used to distinguish *P. laevigata* from all isolates listed in this section of the key. See also *P. laevigata*, section 25. *P. laevigata* from *Betula nigra* is an exception, however, since it does not grow on white pine. These two isolates can be separated from each other by the predominantly white mycelium of *P. laevigata* on *Betula nigra* and the yellowish mycelium of *P. laevigata* on *Betula occidentalis*. In general, isolates of this species grow faster at room temperature than those of *Fomes nigricans*.) Pl. VI, Fig. 1.

Poria laevigata on *Betula nigra*, Virginia. (Predominating colors of cultures more whitish than yellowish, but this feature does not apply to all isolates of *P. laevigata*. Unlike most isolates of *P. laevigata*, this one grows over white-pine blocks, in one-year-old cultures.) Pl. VI, Fig. 2

Fomes nigricans U. 42 on *Betula kenaica*, Moose Pass, Alaska (predominating

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Agar cultures have been described in Paper VIII (22 [1936]: 275–295) of this series.

The genera Fomitiporia and Fomitiporella are separated by W. A. Murrill, "Polyporaceae," *North American Flora*, 9 (Part I, 1907; Part II, 1908): 1–131 on the basis of spore color. The spores are said to be hyaline in Fomitiporia and brown in Fomitiporella. The specimens have been compared with the types, but since spore color is often hyaline at first and later brown in some of the specimens of these genera, it was believed best to reserve the revision of species and generic concepts of these groups for a later study.

colors of cultures more yellowish than whitish, but this feature does not apply to all isolates of *Fomes nigricans*).

25. Mycelium without wintergreen odor in two-week-old petri-dish cultures at 30° C.

A. Mycelium in one-year-old red-gum block cultures growing so luxuriantly that the flask is practically filled with mycelium and often forming so that entire flask is filled with fungous growth; blocks usually hidden from view completely

Fomes Everhartii (form *dryophila*, undescribed) on *Quercus sp.*, Oklahoma. (Lines more black or brown than purplish and not abundant enough to form large patched or red or purplish areas. Predominating colors of cultures are "warm buff" or "antimony yellow." Mycelium growing so luxuriantly that even the agar is drawn away from the flask and enveloped so as to form a "plug.") Pl. IX, Fig. 4

Fomes Everhartii on *Quercus imbricaria*, Michigan. (Lines more black or brown than purplish, present but not abundant enough to form large purplish patches. Predominating colors of cultures are "warm buff" or "antimony yellow." Mycelium growing so luxuriantly that even the agar is drawn away from the flask and enveloped so as to form a "plug.") Pl. X, Fig. 1

Fomes robustus on *Betula nigra*, Virginia. (Lines more black or brown than purple and not abundant enough to form large purple patches. Mycelium exhibiting luxuriant growth, but not to the extent that the shapes of the blocks are so masked as to be entirely hidden from view as in *Fomes Everhartii* isolates. Mycelium not so luxuriant that even the agar is drawn away from the flask and enveloped to form a "plug.") Pl. XIV, Fig. 4

Unknown Poria on *Quercus laurifolia*, Florida. (Lines more purplish than black or brown, abundant enough to form large areas of purple patches. Shape of block hidden from view. Mycelium not growing so luxuriantly that even the agar is drawn away from the flask and enveloped so as to form a "plug.") Pl. VII, Fig. 4

A. Mycelium in one-year-old red-gum block cultures not so luxuriant that the flask is filled with mycelium, general shape of blocks not

hidden from view by fungous growth, plug of mycelium not forming, i.e. mycelium not clinging to walls of flask but often supporting both agar and blocks

Fomes robustus on *Betula nigra*, Virginia (predominating colors of cultures mostly "warm buff" or "antimony yellow," as in *F. Everhartii*). Pl. XIV, Fig. 4

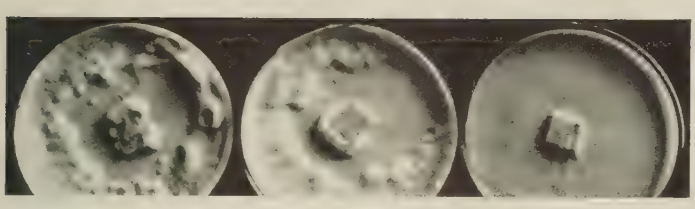
Fomitiporia dryophila, Race I, on *Quercus sp.*, Florida (predominating colors of cultures more yellow than those of *F. robustus* or *F. Everhartii*, i.e. "cream color" or "Naples yellow." "Plugs" of mycelium not formed as in *F. Everhartii*). Pl. V, Fig. 1

Fomitiporia Earleae, Race II, on *Liquidambar Styraciflua* (predominating colors of cultures are those of *F. robustus*[5] and *F. Everhartii*). Pl. VIII, Fig. 2

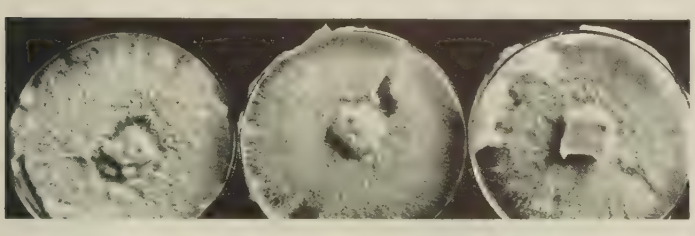
University of Michigan

[5] The fruiting bodies of *Fomitiporia Earleae* and *Fomes robustus* have much in common, and the two fungi are so very closely related that present distinctions may not warrant their separation, at least with reference to specific differences. One may be a resupinate or some other form or race of the other. Fruiting bodies of *F. Earleae* are more likely to refract light than those of *Fomes dryophilus*, but this feature, like other characters of both the fruiting bodies and mycelium in culture, appears relative.

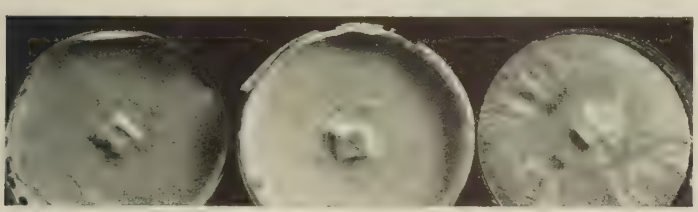
PLATES I–XIV



Poria rufa on *Picea glauca*, Fort Wrigley, Northwest Territories



Lenzites trabea from United States Division of Forest Pathology, Forest Products Laboratory, Madison

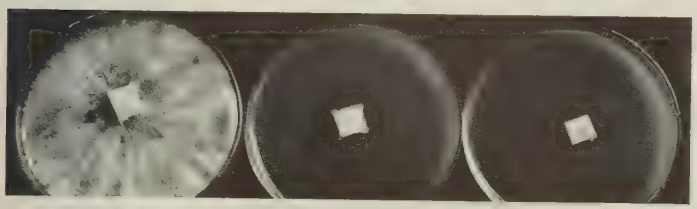


Poria unita on *Quercus sp.*, Michigan

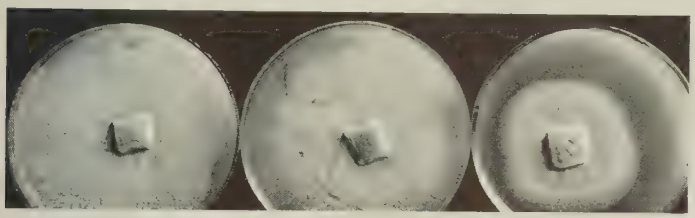
Poria unita pulchella, Selkirk, Yukon Territory

Cultures kept at 25°, 30°, and 35° for 14 days

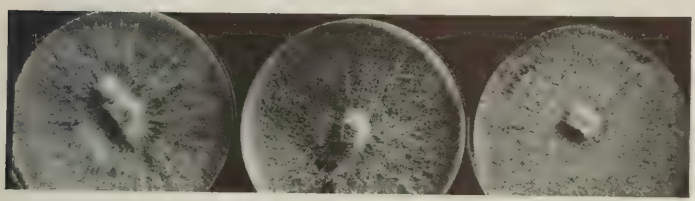
Poria unita pulchella, U. 26, on *Populus balsamifera*, Burnt Island, Great Slave Lake, Northwest Territories



Polyporus alboluteus on *Picea sitchensis*, Juneau, Alaska

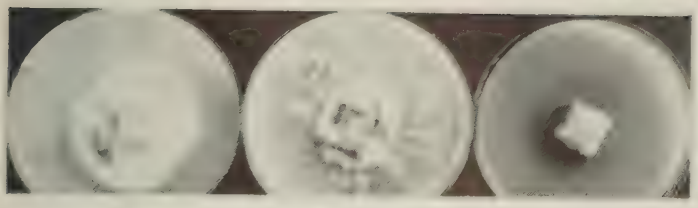


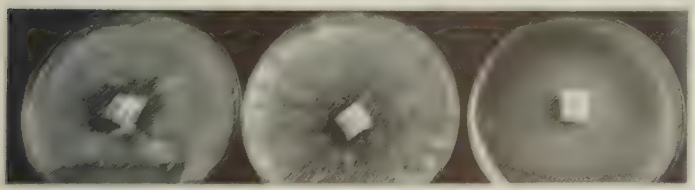
Poria spissa, substratum unknown, Michigan

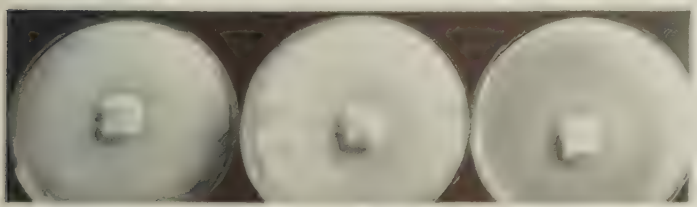


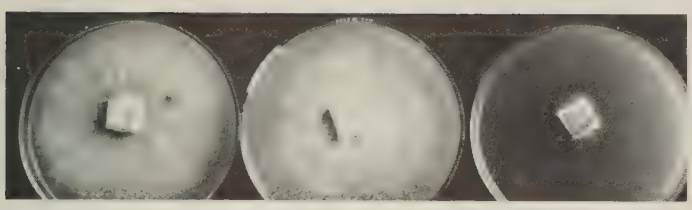
Poria semitincta, U. 23 (growth variable), on *Quercus marilandica*, North Carolina

Cultures kept at 25°, 30°, and 35° for 14 days

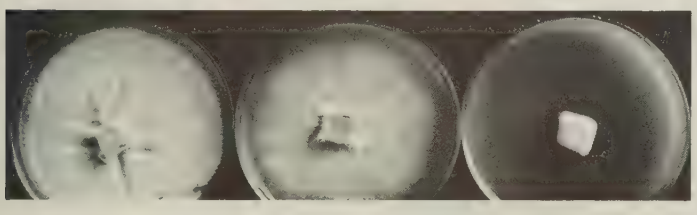




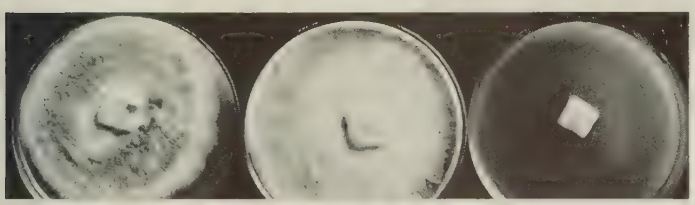




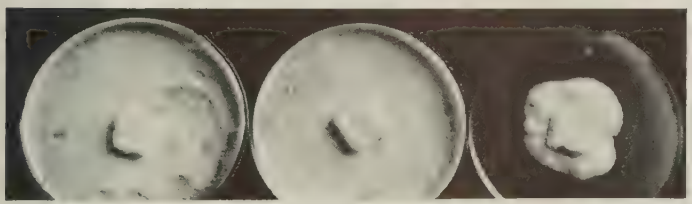
Fomes subroseus on *Larix laricina*, Michigan



Poria purpurea on *Pinus contorta*, Jasper National Park, Alberta

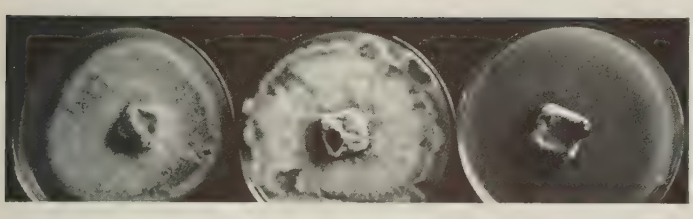


Poria nigra, from United States Division of Forest Pathology, Washington, 71073

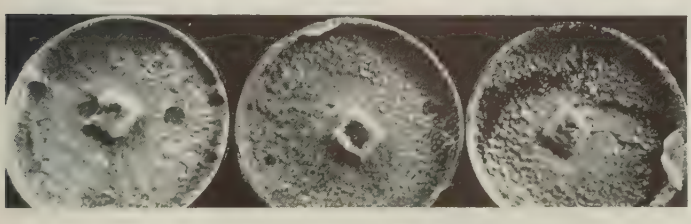


Poria nigra, growth variable at 35° C., from United States Division of Forest Pathology, Washington, 71099, on *Quercus velutina*, Illinois

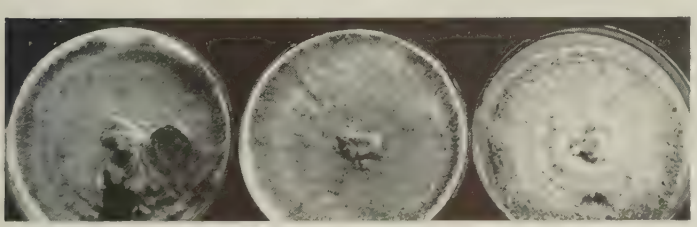
Cultures kept at 25°, 30°, and 35° for 14 days



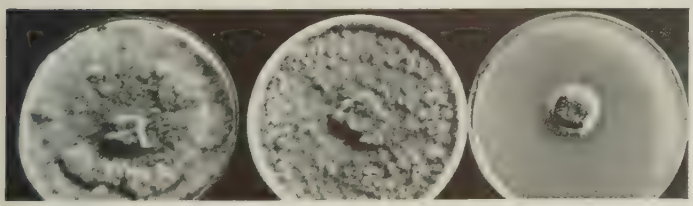
Fomitiporia dryophila, Race I, on *Quercus sp.*, Florida



Fomitiporia dryophila, Race II, on Carpinus, Louisiana

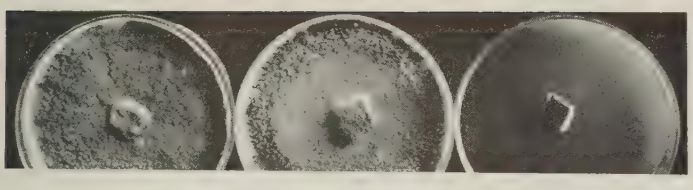


Poria spiculosa on *Carya sp.*, from United States Division of Forest Pathology, Washington

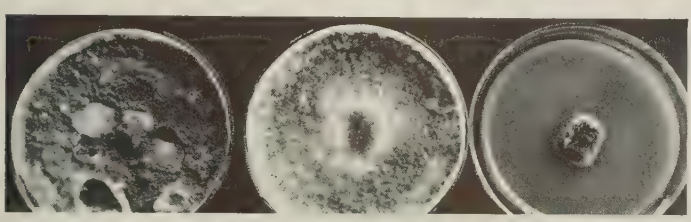


Poria laevigata on *Acer sp.*, Michigan

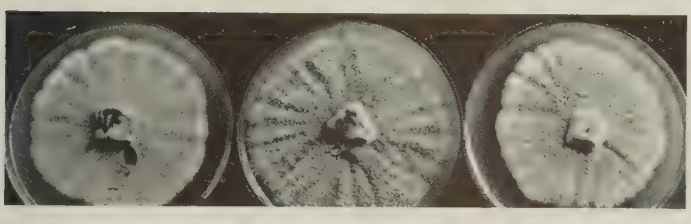
Cultures kept at 25°, 30°, and 35° for 14 days



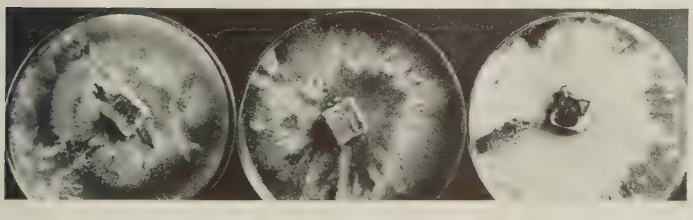
Poria laevigata on *Betula occidentalis*, British Columbia



Poria laevigata on *Betula nigra*, Virginia

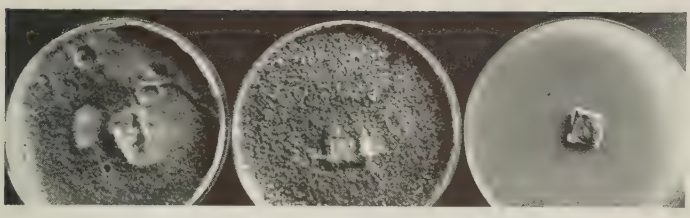


Fomitiporia flavomarginata on *Quercus nigra*, South Carolina

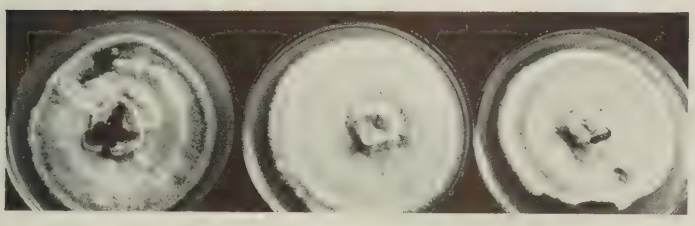


Lenzites saepiaria on *Picea mariana*, Michigan

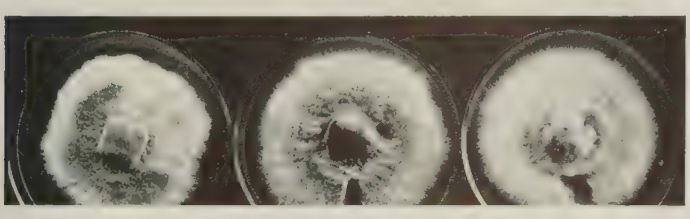
Cultures kept at 25°, 30°, and 35° for 14 days



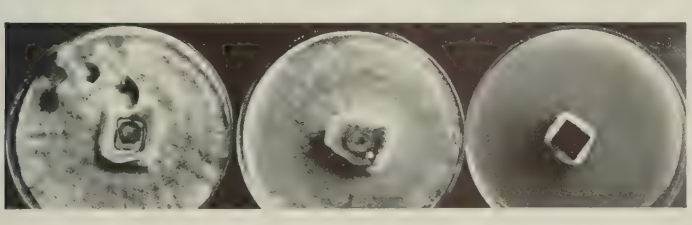
Fomitiporella floridana?, Race I, on Carpinus, Virginia



Fomitiporella floridana, Race II, on *Quercus phellos*, Arkansas



Fomitiporella floridana, Race I, on *Quercus nigra*, South Carolina



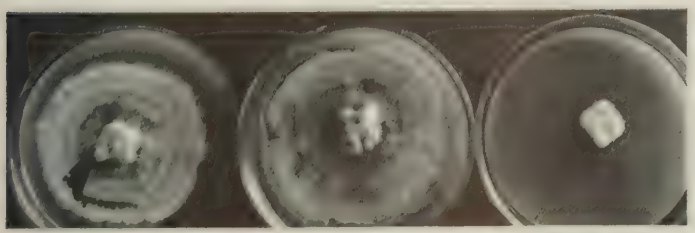
Unknown Poria on *Quercus laurifolia*, Florida

Cultures kept at 25°, 30°, and 35° for 14 days

Fomitiporia Earleae, Race I, on *Nyssa biflora*, Florida

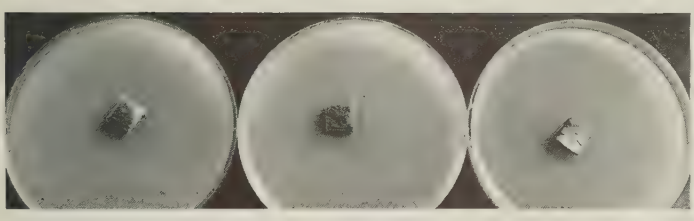
Fomitiporia Earleae, Race II, on *Liquidambar Styraciflua*, Georgia

Unknown resupinate X on *Betula kenaica*, Moose Pass, Alaska

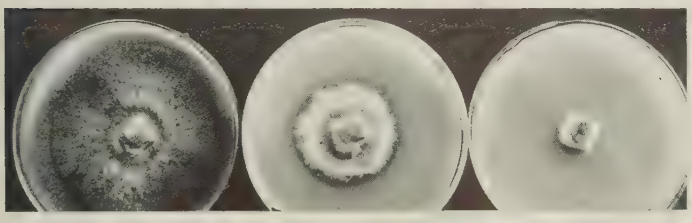


Fomes nigricans on *Betula alba papyrifera*, Minnesota

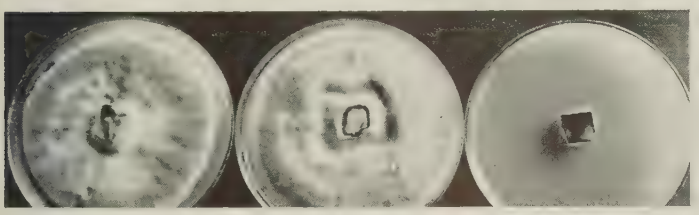
Cultures kept at 25°, 30°, and 35° for 14 days



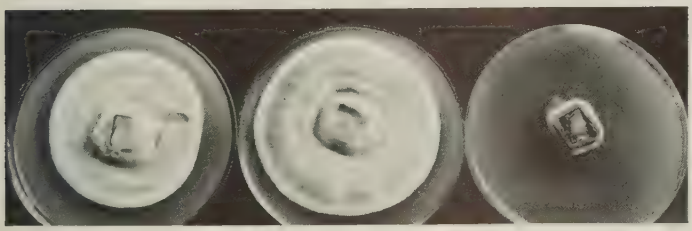
Fomes nigrolimitatus 8 F. on *Tsuga heterophylla*, Wrangell, Alaska



Polyporus radiatus on *Betula kenaica*, Moose Pass, Alaska

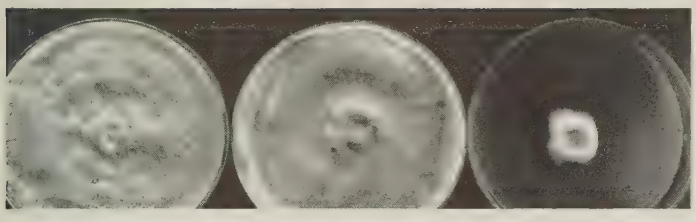


Fomes Everhartii on *Quercus borealis maxima*, Michigan

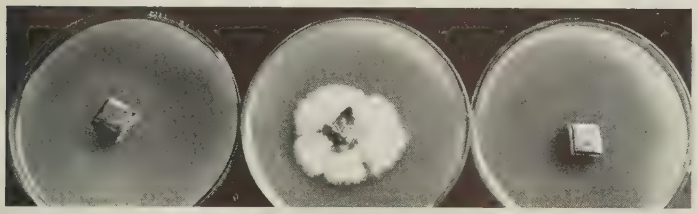


Fomes Everhartii (form *dryophila*, undescribed) *Quercus sp.*, Oklahoma

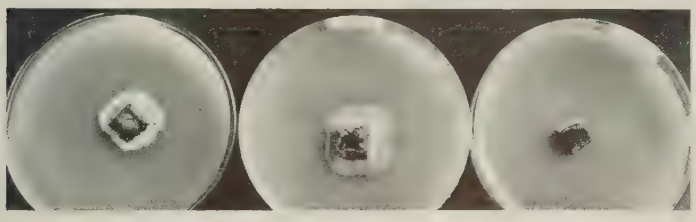
Cultures kept at 25°, 30°, and 35° for 14 days



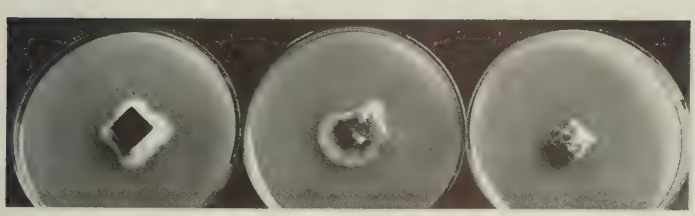
Fomes Everhartii on *Quercus imbricaria*, Michigan



Poria Tsugina on *Abies concolor*, Colorado

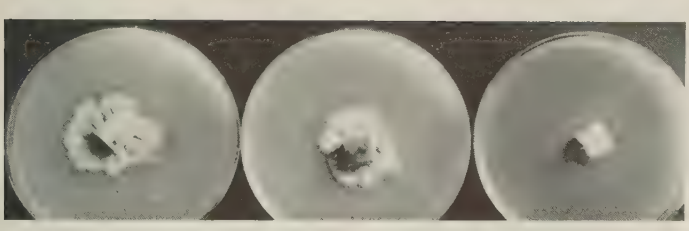


Poria Tsugina on *Tsuga heterophylla*, British Columbia

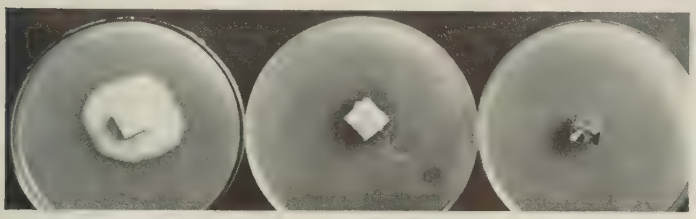


Poria Tsugina on *Tsuga canadensis*, Michigan

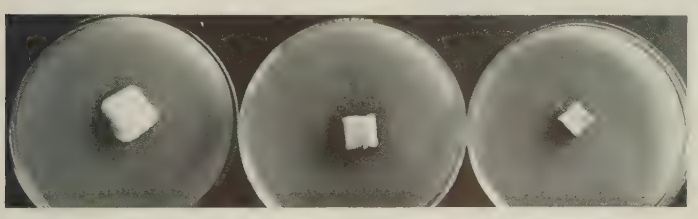
Cultures kept at 25°, 30°, and 35° for 14 days



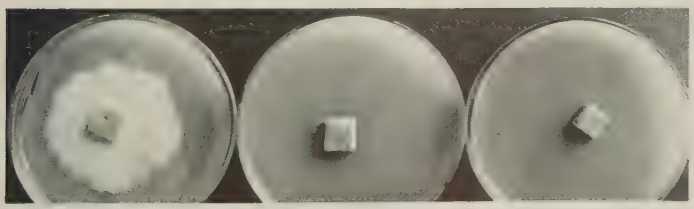
Trametes isabellina 6 W. on *Picea glauca*, Selkirk, Yukon Territory



Trametes isabellina 10 W. on *Picea glauca*, Selkirk, Yukon Territory

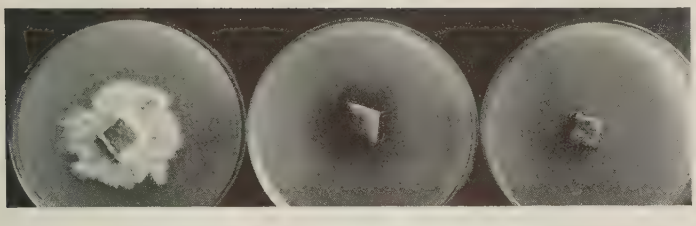


Poria ferrea on *Alnus sinuata*, Skagway, Alaska

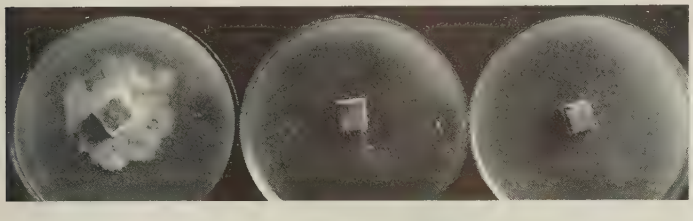


Poria ferrea on *Alnus rubra*, Oregon

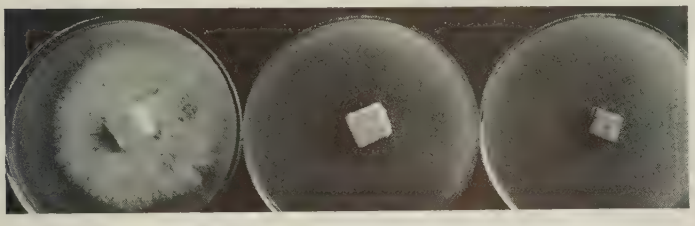
Cultures kept at 25°, 30°, and 35° for 14 days



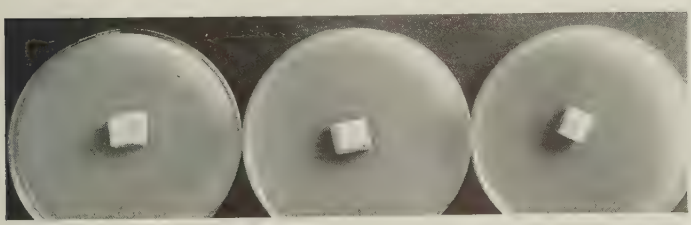
Poria ferrea on *Acer macrophyllum*, Oregon



Poria ferrea on *Corylus sp.*, Oregon

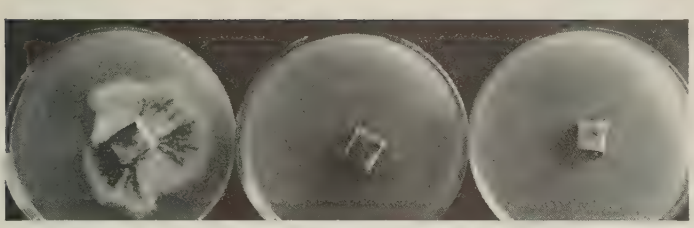


Poria ferrea on *Salix sp.*, Oregon



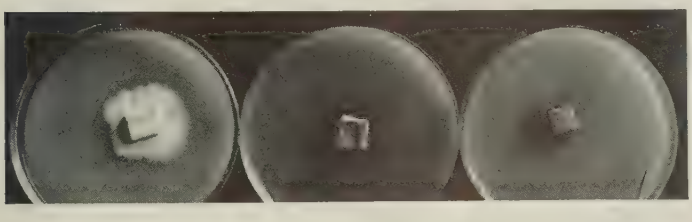
Pora ferrea 9 on *Abies sp.*, Oregon

Cultures kept at 25°, 30°, and 35° for 14 days

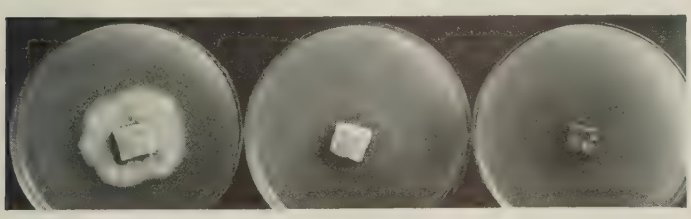


Poria ferruginosa on *Acer saccharum*, Michigan

Poria ferruginosa on *Thuja occidentalis*, Minnesota

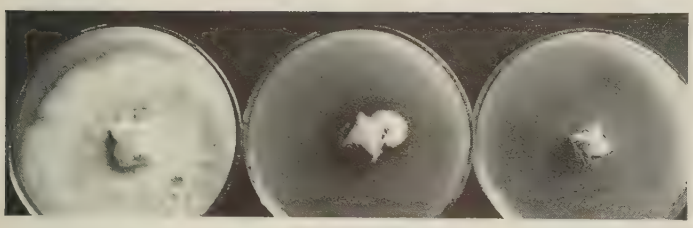


Poria ferruginosa (variable growth at 25° C.) on *Prunus serotina*, Michigan

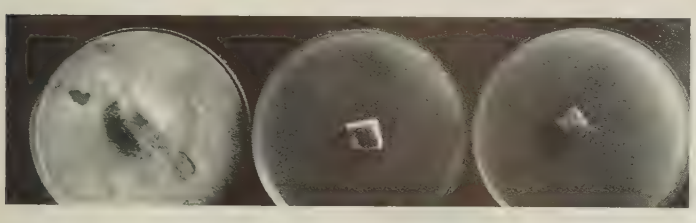


Poria ferruginosa 33 on *Thuja plicata*, Oregon

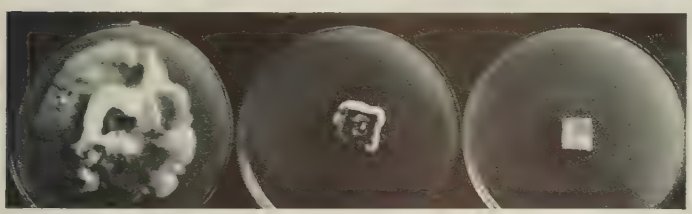
Cultures kept at 25°, 30°, and 35° for 14 days



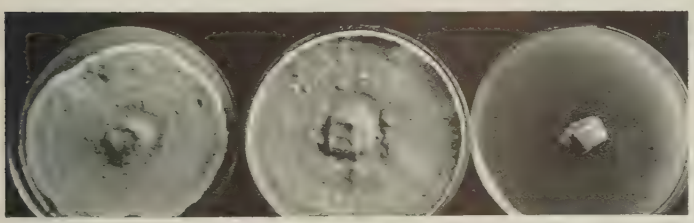
Poria ferrugineofusca on *Pseudotsuga taxifolia*, Oregon



Poria Weirii on *Thuja plicata*



Poria prunicola on *Prunus serotina*, Michigan



Fomes robustus on *Betula nigra*, Virginia

Cultures kept at 25°, 30°, and 35° for 14 days

PRESENT INDICATIONS OF FUTURE TRENDS IN MICHIGAN FOREST INDUSTRIES

MURLYN B. DICKERMAN

EVERY national crisis produces important changes in our economic life. Already there are many indications that the impact of World War II upon the forest industries has forced new trends and adjustments. It is worth while to analyze these new trends and to determine whether they will be carried over into peacetime, and if so, what effect they will have upon the industries themselves and the forest resource on which they depend.

Michigan, producing nearly half of all the lumber in the Lake States, is a strategic state in which to observe these developments. The Upper Peninsula is one of the few important centers of hardwood-lumber production. Veneer cut in this area supplies a large part of the hardwood-veneer requirements for the airplane construction program of the United Nations. Nearly 40 per cent of the total facilities of the hardwood-distillation industry in this country is located in Michigan. Although the manufacture of wood pulp is small when compared with the total produced in the Lake States, some of the specialty papers made at Michigan mills are among the items most urgently needed by the Army and Navy. In these primary forest industries changes can be observed. The following are some of the most significant ones.

THE GROWING IMPORTANCE OF SMALL SAWMILLS

One of the most noticeable tendencies since the war has been the relative increase in the total volume of lumber cut by small mills [1] (Fig. 1). In 1941 these mills sawed nearly a third of the lumber. By 1943 their output amounted to almost half of the entire lumber production in the state. This shift, although evident prior to the war, has been greatly accelerated during the war, and

[1] The term "small mills" refers to sawmills cutting less than five million board feet of lumber annually.

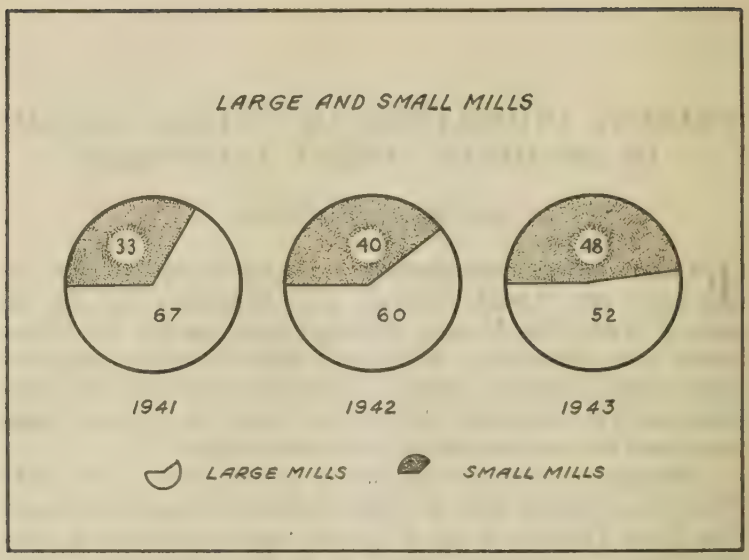


FIG. 1. Percentage of total yearly lumber production cut in Michigan in 1941, 1942, and 1943 by large and small mills

the prospects are that the percentage coming from small mills in the future will be even greater.

There are several reasons for this increase. Since 1941 four of the large sawmills in the Upper Peninsula have closed permanently and are in the process of liquidating their plants. Practically none of the large mills has operated continuously at full capacity, and only one or two have been able to run more than one shift a day. Furthermore, the depletion of adjoining timber tracts, shortages of manpower and equipment, and high operating costs have retarded lumber production in large mills more than in small ones.

On the other hand, during this period small mills have shown a remarkable ability to turn out lumber. In lower Michigan, for example, where there are more than four hundred small mills, the output in the last six months of 1943 was 26 per cent greater than in the same period of 1942, while that in large mills in the Upper Peninsula was 23 per cent less.

There may be some concern regarding the quality of the lumber

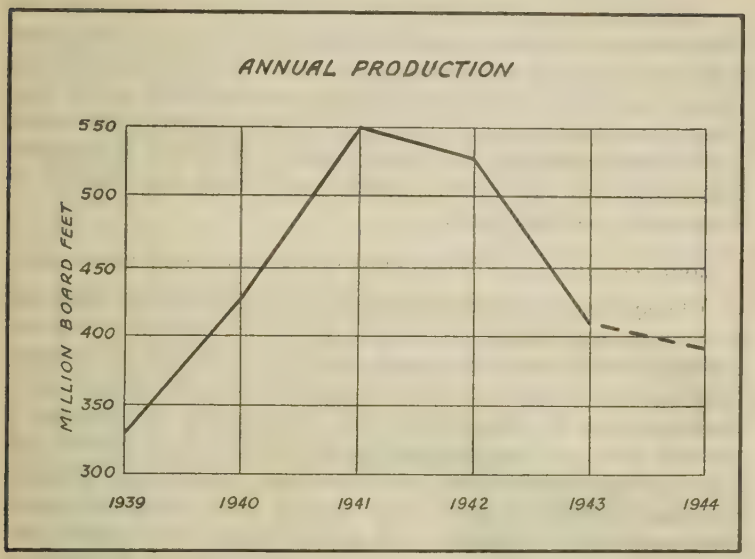


FIG. 2. Annual lumber production of Michigan during the first years of World War II

from small mills. The record during the past two years (1942–44) indicates that well-built and permanently established sawmills, operated by competent mill crews, are fully capable of making high-grade material. Some of the best lumber now going into the war industries is coming from small band and circular mills cutting one to two million feet a year.

After the war the labor supply will undoubtedly be plentiful, and equipment shortages will soon be overcome. But the absence of large timber tracts and the probability that the remaining timber will be located on the more difficult logging "chances" and in relatively small quantities will tend to center more and more lumber operations in small mills. Although a shift from large to small mills will increase proportionately the output of the small mills, it is inevitable that the annual cut in the postwar period will be less. Already lumber production in Michigan has dropped 26 per cent — from 550 million board feet in 1941 to about 415 million in 1943 (Fig. 2).

This swing toward small mills is to be desired from both the economic and the forest-utilization standpoint. In most areas these mills can be readily supplied on a sustained basis because their log requirements are more nearly in balance with available timber supplies. Under such a condition small sawmills can become a permanent part of local industrial life, making possible fuller use of available forest resources and assuring steady employment and stability to communities in rural areas.

MORE SAWMILLS MANUFACTURING SECONDARY WOOD PRODUCTS

Closely connected with the growing importance of the small mill is the increasing number of sawmills which are combining with the sawing of rough lumber the manufacture of secondary wood products. This movement is particularly noticeable in lower Michigan and to some extent in the Upper Peninsula. One sawmill, for instance, is making parts for farm implements, such as hayracks, shovel and rake handles, wagon bodies, and stoneboats. Another has installed an automatic lathe to make wood turnings, while others are assembling such items as factory truck platforms, door mats, onion and celery crates, and railroad and mine wedges. Two small mills are reworking industrial blocking, cutting it to the final size, boring holes at proper spacings, and shaping for blocking railroad shipments of heavy machinery.

Now that these mills and others have found they can manufacture such items and have developed trade relations with industrial and agricultural outlets, it is likely that many similar articles will continue to be made by small concerns after the war. Greater returns from manufacturing secondary products will be a further reason for sawmills to engage in this type of work. Furthermore, although low-grade lumber is temporarily in big demand, there is no question that sawmill operators will again be faced with the problem of finding a market for their lower grades. By cutting up this material and prefabricating it some of the difficulties of marketing low-grade lumber can be overcome.

The combination of primary and secondary processing means closer utilization of both woods and mill waste, a factor which can help to make better forest practices pay and give part-time employment to many people in rural areas. This should be encouraged and receive further development.

GREATER UTILIZATION OF HEMLOCK LOGS IN PULP MILLS

The reduction of pulpwood receipts, from both domestic and Canadian sources, and the increased requirements for wood pulp are major problems of Michigan pulp mills and will likely continue to be. Since January, 1943, pulpwood inventories in Michigan have declined 33 per cent, and half of the pulp mills in the state now have less than a three months' supply of wood. In part, this shortage can be explained by a steady decline in the volume of wood received from Canadian sources, but equally serious has been the declining production of pulpwood in Michigan.

Partly to offset these shortages, a number of pulp mills in Michigan and Wisconsin have increased their consumption of hemlock logs for the manufacture of wood pulp. In 1941 only 29 per cent of the hemlock cut in Michigan was converted into wood pulp, but by 1943 nearly 43 per cent of the hemlock was used this way (Fig. 3). The rest was purchased by sawmills for lumber.

Hemlock timber will continue to be one of the best sources of domestic pulpwood for Michigan and Wisconsin pulp mills, for the amount of hemlock timber left in the Upper Peninsula is greater than that of any other pulpwood species. Michigan pulp mills will face stiff competition from the sawmills for the saw-log material, even though much of it is best suited for use as pulpwood. They will also have to compete with Wisconsin pulp mills, for much of the remaining hemlock is in the western part of the Upper Peninsula nearer Wisconsin markets. The only other prospect of obtaining a sufficient supply of pulpwood is the possibility that Canada may lift the restrictions on the exportation of wood. However, in view of the large supply of hemlock timber in Michigan, the increased requirements for wood pulp, and the shortage of pulpwood inventories, it is highly probable that the present trend of using more hemlock will continue.

DECLINE OF THE HARDWOOD-DISTILLATION INDUSTRY

With the products from the chemical conversion of wood occupying an important place in the manufacture of many essential commodities, it is somewhat strange that hardwood distillation is declining. Shortly before World War II started one hardwood distillation plant in Michigan closed; in the past year two more have shut

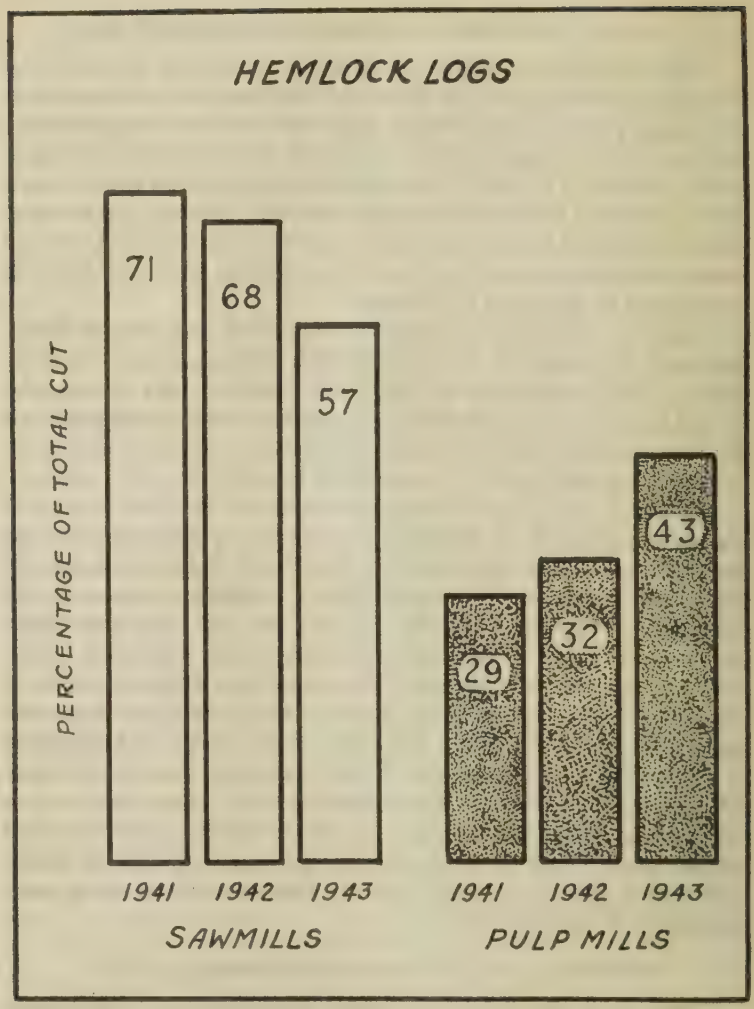


FIG. 3. Distribution of total cut of hemlock logs in Michigan to sawmills and pulp mills

down and are now being dismantled. This leaves only three plants in the state. During the last twelve months these have been operating at less than half of their rated annual capacity.

Among the main factors influencing this decline has been the difficulty of obtaining necessary supplies of wood. The cutting of chemical wood has never been a remunerative occupation, and the migration of woods labor to better-paying jobs during the war has made it difficult to get wood cut and hauled to chemical plants. Also, this shortage has been accentuated by the depletion of chemical wood supplies near the distillation plants, and high freight rates have prohibited hauling it from more distant points where it could have been obtained. However, with the large areas of second-growth hardwoods coming in on the cutover lands, and an increase in the labor supply after the war, the supply problem should be eased. If some adjustment can be obtained in freight rates so that wood can be hauled to existing distillation plants, there should be more than enough raw material to meet the future needs of the industry.

Yet the future of the industry is not at all certain. Apparently the difficulty lies in the inability of wood chemical plants to compete successfully with the synthetic manufacture of acetic acid and alcohol. Although having a monopoly on charcoal production should be helpful, the returns from charcoal alone are not enough to cover the operating costs. Indications are that unless through research new processes and diversified products are found, only the best-equipped and the most efficient hardwood distillation plants will survive. The decline of this market will be a severe blow to good forest practices because it provides one of the best markets for inferior species, tops of trees, thinnings, and cull logs.

LEVELING-OUT OF SEASONAL LUMBER PRODUCTION

Another trend, the implications of which are not yet entirely clear, is the leveling-out of the monthly lumber production since June, 1942. Instead of having high and low periods, the tendency has been for the industry to operate more steadily throughout the year. This became most noticeable in the first half of 1943, when in place of the usual big drop in the spring months there was a gradual increase (Fig. 4). For the rest of the year it was about the same. Whether or not this is only a temporary periodic shift is, as yet, difficult to say, but at least the advantages are many.

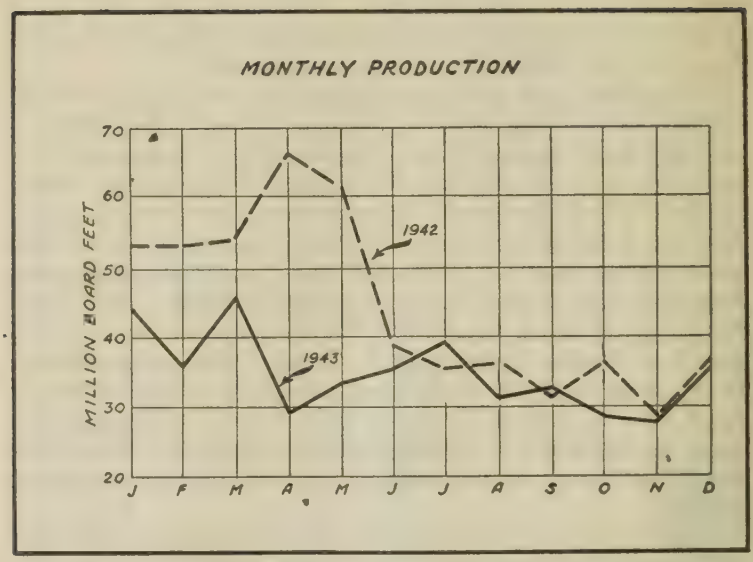


Fig. 4. Monthly lumber production of Michigan sawmills in 1942 and 1943

This elimination of the high and low periods in 1943 can to some degree be accounted for by the shortage of manpower. In trying to keep their crews together employers had to provide steady work for them. Whether in the postwar period, with an ample supply of labor, this practice will continue is not certain, but all-year employment does eliminate the disadvantages of seasonal work. It helps to develop skilled logging and mill crews, and that means greater efficiency and higher quality lumber. Furthermore, steady month-to-month output will lower operating costs, for in both sawmills and small secondary wood-using plants economy frequently depends upon the full and continuous use of plant facilities.

The lumber industry in the State of Michigan has demonstrated that it can operate on a relatively stable year-round basis. There is every reason to believe that what has been done under war conditions can also be accomplished in peacetime.

These are a few of the new trends and adjustments which are coming to the front in the forest industries of the state under the

stress of war. If they are found to be economically sound, they may be continued into peacetime and, to some extent, may help to compensate for the strains of the war period. By recognizing these changes early and anticipating the adjustments that inevitably will follow, the forest industries, managers of forest land, and local governments should be in a better position to plan for the future.

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